Cognitive neuroscience:
Implications for career development strategies and interventions

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Executive Summary

This report summarises some of the key ideas from cognitive neuroscience on the timeline of development of young people (from 5-24 years) and the specific implications for career development strategies and interventions.

Research findings about the skills that underpin decision-making are outlined (part 2) and a typical timeline of their development is presented (part 3). A link between the cognitive neuroscience to existing educational approaches is made (part 4). Characteristics of strategies proven to be effective in developing these skills are identified (part 5) as are some pitfalls (part 6). These strategies are mapped onto the timeline (part 7) and specific areas of recommendation are addressed (part 8).

The areas of recommendation are:

1. ***Levelling the playing field:*** using the development of the skills that underpin decision-making to differentially support students from low socio-economic status backgrounds;

2. ***Continual challenge:*** the need for a lifelong approach;

3. ***Professional learning:*** building capacity in the education workforce;

4. ***Physical exercise:*** exercise, cognition and the ability to stop and think;

5. ***Use of technology:*** purposeful use of computer-aided learning in career planning;

6. ***Broad approaches, practice and more practice:*** avoiding quick-fixes and the importance of practice;

7. ***Wellbeing*****:** the impact of wellbeing on decision-making and career planning;

8. ***Scaffolding:*** the support that can be given to young people in decision-making and career planning, and the importance of dismantling it;

9. ***Supporting the development of decision-making skills versus supporting decision-making:*** strategies for developing decision-making skills and supporting those young people without them;

10. ***Avoiding categorisation:*** the pitfalls of "neuromyths" and categorisation of students;

11. ***Intervention timeline:*** *strategies and interventions that are appropriate to stages of cognitive development.*

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Contents

Part One

Introduction: Escaping from the moment and the skills that underpin decision-making

Our decisions make us who we are. Each fork in the road creates the need for another decision that sends us along a particular pathway, sometimes returning to where we started, other times along a route that can define our outcomes.

During the twists and turns of any career each step taken, each change of direction, each path not taken can occur as a result of unforeseen circumstances, an emotional response, or a conscious decision. Most likely, the path taken will be a result of a combination of these factors and more. As young people set out on their career development journey, they are similarly influenced by a range of factors, none more important than their ability to make decisions. Children and adolescents may go through the motions of decision-making, but without the cognitive abilities to underpin those processes, the decisions may be uninformed, inappropriate and bound in the moment rather than having a future-orientation. Their aspirations may be limited by their view of themselves and how they perceive the pathways of other similar young people with whom they share socio-economic status, ethnicity, gender, etc. Even when a plan has been made, young people have to bear the plan in mind when acting and making future decisions, to stick to the plan over a period of time and to resist the temptation to discard the plan in favour of short-term gain. More challenging still is being able to recognise when the plan is not working as envisaged and to be flexible enough to make changes as required. All of these processes are cognitively challenging, especially for young people whose brains are still developing, and with them the skills that underpin effective decision-making.

Our almost uniquely human ability to stop-and-think allows us to peer into the future and take control by making informed decisions, planning and prioritising. In making and acting out these plans we are “escaping from the moment”. To make effective decisions about the future, including plans for career development, we must overcome the natural impulse for an immediate pay off for our pressing desires.

In the moment, we are influenced by the milieu created by our senses and emotions, the people with whom we find ourselves, and the places we occupy. We can only react to the press of the input from our senses and our emotional responses to the environment in which we find ourselves. This literally sensational state is not conducive to making informed plans and decisions about careers and future pathways but young people often find themselves trapped in the moment.

When we escape from the moment, our responses are more considered and more measured; we can bear in mind our past experiences and information received. When we escape from the moment, we can build an understanding of our future-selves and our future-world; we can inhibit the impulse to act for short-term gains in favour of prioritised long-term benefit. In short, we can plan ahead and make decisions.

Decision-making is dependent upon processes in the brain, yet we still do not fully understand these processes and how they are expressed in our behaviour. Increasingly, studies in cognitive neuroscience are illuminating these processes and coupled with research evidence from education, psychology and elsewhere, these new insights can

inform our approach to supporting young people's decision-making processes, particularly in relation to their career plans. There is a body of research and a number of different models that attempt to rationalise and inform our understanding of decision-making; on the whole they focus on the ability of adults to make decisions appropriately and effectively. With children and adolescents, the cognitive processes that underpin decision-making are still unfolding and to a large extent, this cognitive development is linked with brain development (e.g. Blakemore & Frith, Paus, 2005, Steinberg, 2005, Royal Society, 2011).

In this report, the cognitive factors that influence decision-making in young people are described and references given that describe the neural correlates with these behaviours. A broad timeline for their development is set out and specific implications for career development interventions are highlighted.

Part Two

Taking control: executive functions

Our earliest years are a frenzy of brain and cognitive development as we start to take control of motor function, the interpretation of sensory information, etc. (Blakemore & Frith, 2005). But it does not end there. The experiences of very young children influence the ways in which they build their cognitive skills that support their school readiness (Bodrova & Leong, 2006). The interplay between the physical development of the brain and the development of behaviour and skills goes on throughout primary school, into secondary and through to our early twenties unlocking various aspects of our cognition. These physiological and physical changes in our brain that constitute development are occurring throughout childhood, adolescence and early adulthood (Best *et al.*, 2009; Blakemore, 2008; Choudhury *et al.*, 2008; Gogtay *et al.*, 2004; Shaw *et al.*, 2006). The ability to make and break connections between brain cells in response to experiences persists throughout adulthood but the changes are no longer driven by the physiological development of the brain.

In this extended period of development from early childhood to early adulthood, a shift occurs from experiencing the world in a purely sensational and emotional way to the application of increasing self-regulation and more thought-through actions. For example, it used to be assumed that teen risk-taking behaviour arose because they did not appreciate the risks associated with their actions. Intervention programs sought to remedy this by informing young people about those risks. In reality, teens do fully appreciate, and often over-estimate, the risks to which they are exposed through certain behaviours (Adams, 1995). What they lack are the cognitive skills to apply that knowledge when making decisions, especially in emotionally charged situations and when social pressures are brought to bear. Their ability to self-regulate and stop-and-think is not fully developed and they are unable to take control of the situation, essentially incapable of doing what they think they should do in favour of what they feel they want to do (Steinberg, 2005, Romer *et al.*, 2011).

Similarly, in choosing career pathways, information is necessary but not sufficient to support decision-making. The information is required in order to inform young people’s decisions but is insufficient. If they are incapable of using that information effectively, and cannot incorporate it into any meaningful future-oriented considerations, they will remain trapped in the moment and unable to take control of the steps along their career pathway. The information becomes most valuable when young people are able to use it to direct their immediate actions toward a goal that lies far beyond the here-and-now.

These self-regulation and stop-and-think skills are called “executive functions”; a range of cognitive processes such as planning, prioritising, verbal-reasoning, problem solving, sustaining and switching attention, multitasking, initiating and monitoring actions. As the term *executive functions* suggests, these abilities exert some control and direction over thoughts and actions. There are three core *executive functions* that are interrelated and seem to underpin the other process such as goal setting, planning, prioritising, etc. that are crucial for decision-making in career development. These core executive function abilities are **impulse inhibition, working memory and cognitive flexibility**.

Impulse Inhibition

In escaping from the moment in order to make effective decisions it is necessary for an individual to be able to resist their habitual responses, and the temptations for short-term gain while simultaneously holding at bay any distractions that will bring them back to the here and now. This ability to **inhibit impulses** is the skill we use to pause and filter our thoughts and actions. It makes possible resisting distractions, selecting where to focus attention, and the weighing of possibilities.

> "This capacity keeps us from acting as completely impulsive creatures who do whatever comes into our minds. It is the skill we call on to push aside daydreams about what we would rather be doing so we can focus on important tasks. It is the skill we rely on to help us "bite our tongue" and say something nice, and to control our emotions at the same time, even when we are angry, rushed or frustrated. Children rely on this skill to … stop themselves from yelling at or hitting a child who has inadvertently bumped into them, and to ignore distractions and stay on task in school." (Centre on the Developing Child at Harvard University, 2011)

In short, inhibitory control is the ability to resist a strong inclination to do one thing in order to do what is most appropriate or needed. (Diamond *et al.*, 2007)

Examples of inhibition of impulses include resisting driving along your usual route to work when you need to go to a different location, or putting aside the delicious chocolate cake in favour of the fresh fruit if you are trying to control your diet. In social situations, the ability to inhibit impulses keeps us from saying the socially inappropriate remark and being polite instead, controls distractions making possible selective and sustained attention, and helps with resisting peer pressure.

> The ability to inhibit a strong behavioral inclination helps make discipline and change possible. (To change, to get out of a behavioural rut, requires inhibition of the strong tendency to continue doing what you've been doing). Inhibition, thus, allows us a measure of control over our attention and our actions, rather than simply being controlled by external stimuli, our emotions, or habitual behavior tendencies. The concept of inhibition reminds us that it is not enough to know something or remember it. A child may know what he or she should do, and want to do that, but not be able to do it because of insufficiently developed inhibitory control (Diamond *et al.*, 2007).

In the decision-making related to career development even if a young person has appropriate levels of knowledge and motivation to follow a selected pathway, without inhibitory control they are unlikely to be able to develop a plan, and even less likely to be able to enact and stick with that plan.

Working Memory

The ability to hold information and ideas in mind, and mentally working with that information over short periods of time is known as "working memory". It has been described as mental workspace or jotting pad that is used to store important information that we use in the course of our everyday lives (Gathercole & Packiam-Alloway, 2008).

Many of our conscious mental processes rely upon working memory. For example, if you were attempting to multiply together 21 and 63 (without a calculator or pen and paper) you would store these numbers in your working memory. Regardless of the strategy you employed, you would likely break the two digit number up in some way, holding the fragments in your working memory, multiply some combination of the fragments together, now holding the results of these operations in your working memory, to finally recombine them through addition. This process puts high demand upon working memory. Several number combinations have to be held in mind, as do the relationships between them if we are to be successful. Without working memory, or a surrogate such as a pen and paper, this arithmetic would be impossible.

As described by Harvard University's Centre of the Developing Child (2011):

> Working memory … provides a mental surface on which we can place important information so that it is ready to use in the course of our everyday lives... It enables children to remember and connect information from one paragraph to the next, to perform an arithmetic problem with several steps, … and to follow multiple-step instructions without reminders. It also helps children with social interactions, such as planning and acting out a skit, taking turns in group activities, or easily rejoining a game after stepping away to get a drink of water.

Building working memory in children lays the foundations for future-thinking processes that impose greater cognitive burden. Future-oriented decision-making such as in career development and planning can create enormous demands on working memory. Appropriate information and experiences from the past must be called to mind and incorporated into the development of future goals.

> Working memory is also the ability to hold information in mind despite distraction (such as holding a phone number in mind while you pause to listen to what someone has to say) and to hold information in mind while you do something else (such as holding a phone number in mind while talking about something else before dialing). The information loaded into working memory can be newly learned or retrieved from long-term storage. Working memory by its very nature is fleeting, like writing on misty glass. The ability to hold information in mind makes it possible for us to remember our plans and others' instructions, consider alternatives and make mental calculations, multi-task, and relate the present to the future or past. It is critical to our ability to see connections between seemingly unconnected items (Diamond *et al.*, 2007).

Cognitive Flexibility

> Cognitive flexibility is the capacity to nimbly switch gears and adjust to changed demands, priorities, or perspectives. It is what enables us to apply different rules in different settings. We might say one thing to a coworker privately, but something quite different in the public context of a staff meeting… As the author of *the executive brain*, Elkhonon Goldberg (2001), notes, "the ability to stay on track is an asset, but being 'dead in the track' is not." Stated differently, self-control and persistence are assets, rigidity is not. Cognitive flexibility enables us to catch mistakes and fix them, to revise ways of doing things in light of new information, to consider something from a fresh perspective, and to "think outside the box." If the "church in two blocks" where we were told to turn right is actually a school, we adjust and turn anyway (Centre on the Developing Child at Harvard University, 2011).

Cognitive flexibility builds on impulse inhibition and working memory but adds an additional element (Diamond et al., 2007). For example, in considering alternative strategies or error corrections, the goal has to be borne in mind while the merits of different approaches are considered. Ways forward that demand least effort, or staying on the existing pathway (even if "dead in the track") may be tempting and emotionally appealing but they must be inhibited if other options are to be thought through. For example, the ability to resist the allure of earning money immediately post-school but in a low-value job requires inhibitory control and also the cognitive flexibility to consider the alternatives and actively choose an alternative career pathway.

In effective decision-making processes, the ability to adjust to new information or changed demands and priorities is required (Bodrova & Leong, 2006; Luria, 1966; Shallice, 1982; Stuss & Benson, 1986). In career development, this flexibility allows individuals to shift priorities and explore alternative scenarios as they think through how different the future might be from their current experiences and the potential implications of their decisions. Cognitive flexibility can help to keep options open when appropriate, allowing for the switching between different pathways and outcomes. There may be a desire to make a snap decision just to resolve the discomfort that this ambiguity might cause in preference for some apparent certainty.

> People often prefer the known over the unknown, sometimes sacrificing potential rewards for the sake of surety. Overcoming impulsive preferences for certainty [is necessary] in order to exploit uncertain but potential lucrative options (Huettel *et al.*, 2006).

The ability to inhibit this impulse, in combination with cognitive flexibility are required if young people are to avoid prematurely locking-in to a particular pathway which may turn out to be sub-optimal or inappropriate. Of course, along a career pathway numerous barriers and difficulties are likely to be encountered and the need to employ cognitive flexibility does not excuse the individual from the need to be persistent and apply effort where appropriate. However, young people without that flexibility tend to adopt one of two strategies when they encounter a significant problem; they either continue along the same "dead end track" continuing to employ strategies and making choices that are demonstrably not working or they withdraw completely (Blackwell, et al., 2007). Young people with higher levels of cognitive

flexibility will consider whether the goal remains desirable or is achievable at all, and if they decide that it is, they will find other ways to achieve it drawing on the experiences and expertise of their friends, parents, teachers and others who might be able to support them.

> Flexibility of thinking is also called into play when students interpret words or language that may be ambiguous, draw inferences and conclusions, and process redundant information; actions required to process most written texts. Students need to prioritise and reprioritise information in an effort to make the text useful for their particular purpose. (Meltzer & Krishnan, 2007)

For many young people when they set out to explore the pathways toward the world of work they will find themselves in unfamiliar territory. This puts enormous demands upon executive functions and it cannot be assumed that they will be able to effectively interpret the information they receive and the experiences they have. Repetition and reinforcement of information and experiences can be very important for all students regardless of their level of executive functioning. Students with lower levels of executive function will need repetition in order to reinforce their ability to effectively use the information given to them or to derive meaning from their learning experiences. Students with higher levels of cognitive flexibility can have the same experience multiple times but take something different away from it each time. Thus, interventions and resources to support decision-making in career development can be designed to incorporate repetition that will serve a wide range of students, especially where the context in which they are working is unfamiliar.

The extent to which young people have developed executive functions has been shown to profoundly affect their outcomes in terms of education, health, income and criminal behaviour (Moffitt *et al.*, 2011; Margot *et al.*, 2006; Mischel *et al.*, 1989).

For example, a study carried out in Dunedin, New Zealand followed one thousand or so children from birth through to adulthood and measured a range of outcomes. Individuals were assigned to a quintile depending on their childhood level of self control. In the graphs below Quintile 1 had the lowest levels of self-control and Quintile 5 the highest.

Of the group with the lowest levels of childhood self-control (Quintile 1), just over 40% left school without any qualifications compared to less than 5% of those in quintile 5. The proportion of individuals without any educational qualifications decreased as the levels of childhood self-control increased across the groups (Figure 1A, page 8). This pattern was mirrored quite closely for the rate of adult criminal convictions (Figure 1B) in the population.

Given the correlation between childhood levels of self-control and school qualifications, it is unsurprising that similar correlations exist with socio-economic status and income (Figure 1C). Typically, children from low socio-economic status

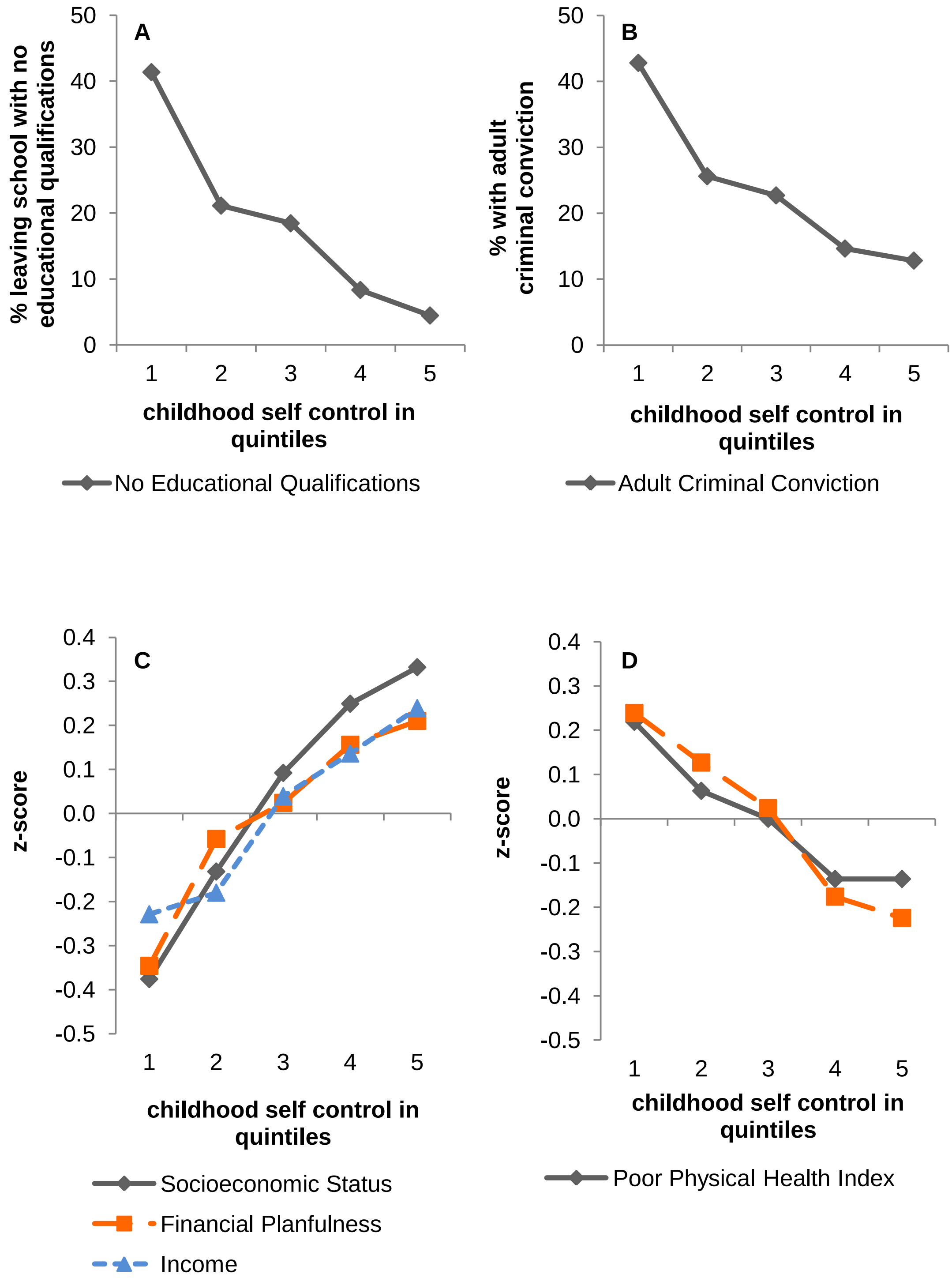

Figure 1: Impact of childhood self-control on outcomes in adulthood Children with lower levels of self-control are more likely to (**A**) leave school without any formal qualifications, (**B**) have a criminal conviction, (**C**) have financial difficulties, lower income and have lower socioeconomic status, and (**D**) have poorer health outcomes by 32 years old (data from Moffitt et al., 2011). (Each quintile contains the same number of people. The Z-score is the number of standard deviations from the mean represented by each group.)

backgrounds have lower levels of self-control and executive functions. They are less likely to be able to make effective planning decisions about who they want to be, the careers that they want to pursue and how to go about it. Thus, young people from low socio-economic status backgrounds are less likely to develop effective executive functions that underpin their day-to-day decision-making processes. This in turn prevents them from making the most of the educational opportunities available and traps them into low income jobs, low socio-economic status and poorer health outcomes (Figure 1D). The cycle continues with their children with no change from generation to generation. Given that poverty and low socio-economic status does run in families, it is tempting to think that there is an underlying genetic basis. However, research such as the Dunedin study shows that while there is likely to be a genetic component that influences young people's ability to make the most of the education and employment opportunities available to them, the characteristics of their environment are crucially important. On the whole, children are not genetically predestined to be limited to low income employment. Their low socioeconomic status background often means that they do not see executive functions being modelled to them, they do not value these skills and they do not get the opportunity to practise and develop them. These are all characteristics of their experiences and the environment in which they grow up, not their genetic make-up. Those children who are supported to develop executive functions enjoy better outcomes than those who do not.

The Dunedin study was designed as an observation-only study but some children did, for whatever reasons, improve their executive functioning and self-control.

> "… those children who became more self-controlled from childhood to young adulthood had better outcomes by the age of 32 y, even after controlling for their initial levels of childhood self-control". (Moffitt et al., 2011)

This finding suggests that levels of executive functions can be improved and for those individuals that are supported to do so, these enhanced skills lead to enhanced outcomes including educational attainment, income and socio-economic status. Alexis Piquero, professor of criminology at Florida State University said in commentary on the research "The good news is that self-control can change. People can change".

Together, *impulse inhibition*, *working memory and cognitive flexibility* allow an individual to escape from the press of the moment by taking control of their thoughts and actions, essentially allowing them to stop-and-think (Best *et al.*, 2009; Grosbras *et al.*, 2007; Andrews-Hanna et al., 2011). **Young people with these appropriately developed skills can more effectively think about the future, determine where they want to get to, and plan how they are going to go about it.**

Appropriate support to build and hone these executive function skills is important at every stage of development if young people are going to be able to effectively make decisions about their own career development and put those plans into action. For those students who do not have these skills and so cannot work with their understandings about themselves, and the educational and employment pathways before them, traditional educational and career counselling is unlikely to have best effect unless they engage with an appropriate process to scaffold decision-making. For those young people with particularly low levels of executive function, decisions need not be taken for them but a surrogate for executive functions may be needed as they make their own decisions. This is discussed more on page 27.

Executive Function Development With Age

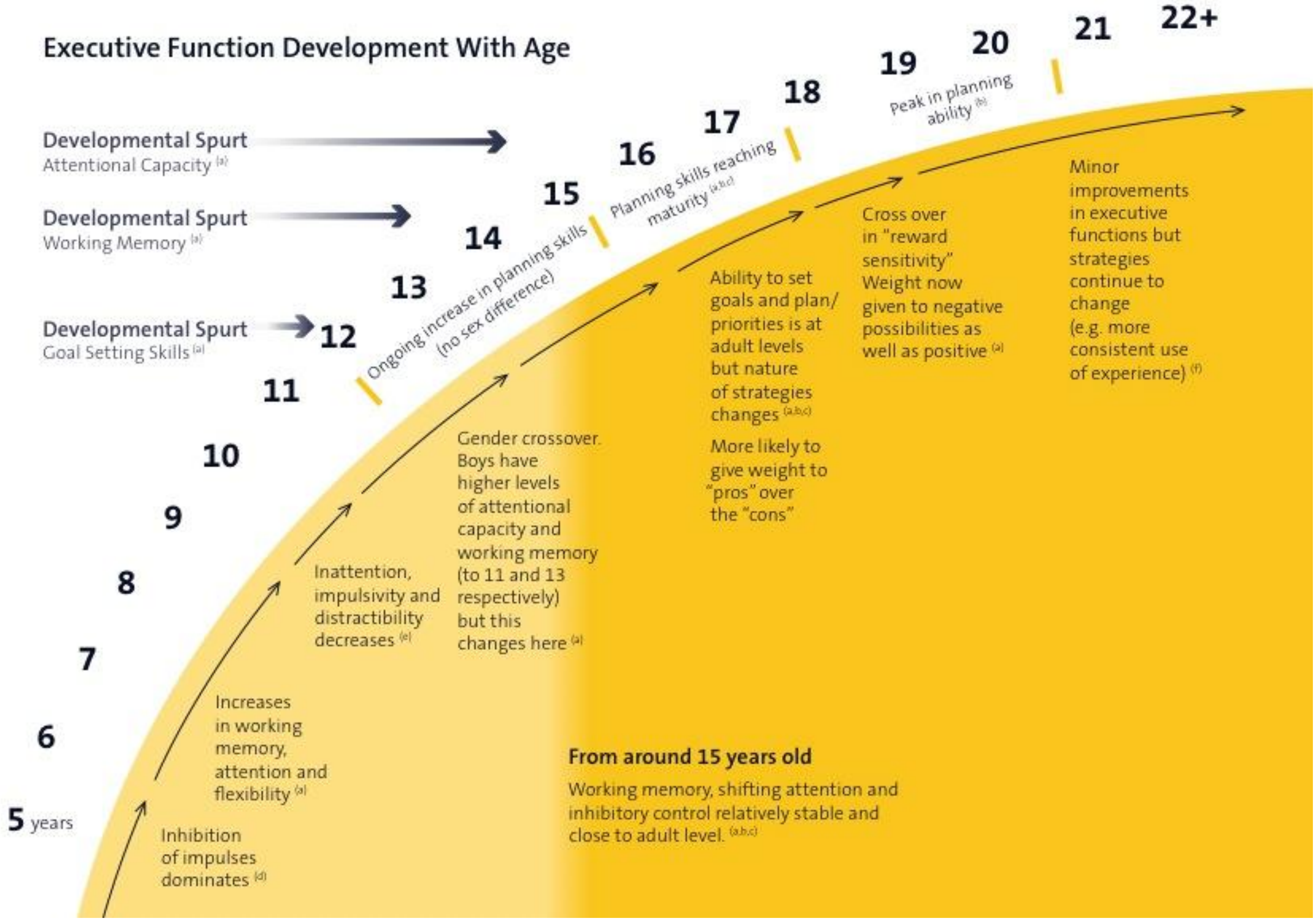

Figure 2 (page 10)**: Executive function development with age**
The timeline gives a broad indication of the development of executive functions with age. Data associated with each point can be found in the literature (a) Anderson & Anderson (2001); (b) Best *et al.,* (2009); (c) Huizinga *et al.,* (2006); (d) Senn *et al.,* (2004) (e) Klimkeit *et al.,* (2004); (f) Cauffman *et al.,* (2010); and a further discussion about typical executive function development can be found in Gathercole *et al.,* (2004); Zelazo & Müller (2002); Levin *et al.,* (1991)

Part Three

A timeline of executive functions and decision-making skills

A host of factors will influence the time course over which an individual will develop the executive function skills underpinning decision-making. Genetic predispositions can influence cognitive development but the characteristics of an individual's experiences also have a profound effect upon their brain development and their cognition (e.g. Hughes, 2011; Royal Society, 2011). Adults and others who shape the characteristics of the environment in which young people find themselves are indirectly changing the way that brain cells are interconnected and thus changing the development of the cognitive skills involved in decision-making. Like almost all other aspects of development, decision-making capability and the underlying processes do not unfold in a way that is tightly bound to chronological age. Across a population broad trends are seen but there is such wide variation across individuals, especially in childhood, such that applying a generalisation to a single child can be unhelpful (Anderson *et al.,* 2001; Huizinga *et al.,* 2006; Lamm *et al*; 2006; Gathercole & Packiam-Alloway, 2008). However, decision-making skills can be developed and the process of decision-making itself can be supported through an approach that takes into consideration the broad timeline of cognitive development and incorporating sufficient flexibility to meet individual needs.

Some of the developmental changes that occur in executive functions through childhood, adolescence and into early adulthood are illustrated in Figure 2. This timeline shows the loose association between changes in these cognitive skills and age. In the early years, a lack of inhibition control tends to dominate and shows the biggest differentiation from child to child (Senn *et al.,* 2004) and the development of this skill is thought to underpin the other executive functions. Children who show higher levels of inhibitory control at this age tend to exhibit higher levels of self-esteem, sociability and academic scores in later life (e.g. Casey *et al.,* 2011, Mischel *et al.,* 1989). Working memory, attentional capacity and cognitive flexibility quickly improve during the primary school years as inattention, impulsivity and distractibility decrease (Anderson *et al.,* 2001; Huizinga *et al.,* 2006; Lamm *et al*; 2006; Gathercole & Packiam-Alloway, 2008).

Toward the end of the primary school years, the development in executive functions continues but a gender crossover gradually occurs. In childhood, boys tend to have higher levels of attentional capacity and working memory than girls of the same age. As they approach adolescence this imbalance swaps over such that female teenagers generally outdo the males.

Through the early teenage years, developmental spurts occur in planning and goal setting skills, working memory and attentional capacity. Across the population, these seem to occur sequentially but, as with many other aspects of human development, individual “growth spurts” can occur across a range of ages and in different orders.

From about age fifteen, working memory, inhibitory control and the ability to sustain and appropriately shift attention are close to adult levels and remain relatively stable with some small increases into adulthood. Improvement in planning skills is also starting to level off but changes are still occurring in the strategies used. Until around seventeen or eighteen years, young people are less sensitive to the disadvantages associated with particular strategies and actions, giving greater weight to the potential advantageous consequences. As adulthood is entered, a cross over in rewardsensitivity occurs where the possibility of negative outcomes gain greater influence than they had in childhood and adolescence. A peak in planning ability occurs around twenty years, though of course this ability is not matched by the experience that can be brought to bear on decision-making and planning in later life. For example, adults use stored knowledge about themselves and draw on their range of experiences when making a decision that requires some self-referencing. In contrast, adolescents rely on more "on-line" self-reflective processes essentially making a decision based mainly on their view of themselves at that specific moment (Sebastian *et al.*, 2008). Thus for many adolescents, even their decision-making can be trapped in the moment and be more likely to be fickle, unreliable and changeable. A decision made on one day may be quite different to a decision made on the next. As a consequence of this ongoing, serial decision-making, it may also seem to outside observers that, as a group, adolescents do not stick to decisions very well when to some extent they may be remaking decisions each day.

Adolescents do have the ability to incorporate external information into their decision-making but it may need to be reinforced and linked to a clear value proposition. That is, while the stop-and-think skills of executive functions are still being refined during adolescence, ongoing decisions and actions are still being influenced by emotional and in-the-moment pressures. A clear value proposition helps give young people a perception of why they might need to make informed decisions, providing an emotional link and an ongoing ability to refer their decisions not just to their existing view of themselves, but also to their view of who they would like to become (Sebastian et al., 2008; Blakemore & Choudhury, 2006; Dumontheil *et al.*, 2010; Heatherton, 2011).

For younger, pre-teen children their perception of their existing and future identity plays a greater role in their decision-making due to even less mature executive functioning. That is not to say that their executive functions do not play a role, that their decision-making cannot be influenced, nor that their skills developed (Bodrova & Leong, 2006). As described above, children’s executive functions influence their ability to capitalise upon the educational opportunities presented to them. Making sense of the world, taking some control of it and being an effective child depends heavily upon these cognitive skills.

However, children are less likely to make explicit well thought through decisions, be able to use those decisions to inform their actions, or to stick to the decisions over time. Their day-to-day decision-making is more likely to be influenced by the immediate view of their existing and future selves. Experiences that they have will be

more effective at influencing their decisions if they influence how they see themselves as learners and future workforce participants. Any information that they receive may not inform immediate decision-making but may be called upon when they are older when more informed decision-making is occurring.

The scheme illustrated in Figure 2 shows a broad indication of executive function development with age. Any such scheme will only ever be indicative and the details will be contestable. Trying to link studies of typical executive function development with age is particularly problematic because of the way in which more demanding tasks differentiate between individuals. For example, on relatively simple tasks for which the demand on executive functioning is low, the average eleven year old performs at the same level as an adult (Huizinga, 2006). If there is an increase in task difficulty then a difference in the performance of adult and child emerges. Similarly, while performance on tasks that require inhibitory control is generally stable from around fifteen years of age, differentiation can be seen on particularly difficult tasks through to the early twenties (Albert & Steinberg, 2011). These findings serve to demonstrate that when tasks are easy adolescents can perform at the same level as adults. Only when tasks are more difficult (e.g., decision-making and career planning) do the differences emerge and these can be apparent even for young adults.

Part Four

Seeing it when it happens: an Australian framework

Prior to the emergence of neuroscience research much of education and our understandings of learning and teaching were based in the cognitive domain with a number of models describing cognitive development over time. These models built upon the solid foundations of the educators' expertise and experience are largely consistent with the emerging evidence from neuroscience so that together they can provide a shared language and significant insights into young people's thinking, learning and cognitive abilities. Piaget's theory of stage development will be familiar to almost all educators and his insights form the basis of more contemporary models that incorporate more recent research evidence and classroom observations. The SOLO (Structure of the Observed Learning Outcome) framework represents one such model, developed in Australia and widely used in education (Biggs & Collis, 1982; Biggs & Collis, 1991; Panizzon & Pegg, 2008; Purdie, 1998). SOLO offers a sophisticated approach to understanding students' cognitive development with some broad indications of cognition development with age and specific descriptions of the levels of understanding through which individual students' conceptual development progresses. Importantly, such models help explain how students build their conceptions and views of the world over time, which will ultimately impact their decisions and their decision-making. It also provides a possible way of conceptualising how students' educational and cognitive development can be incorporated into a career development strategy.

While there are many theories that fit under this broad umbrella, the Structure of the Observed Learning Outcome (SOLO) Model is a cognitive model based upon classroom research. Developed by John Biggs and Kevin Collis in the late 1970s, it has been used as a theoretical framework in higher education (Chan et al., 2002; Purdie, 1998; Wong, 2007), science education (Collis et al., 1998; Levins & Pegg, 1994; Panizzon, 2003), mathematics education (Pegg & Tall, 2005; Watson et al., 1995) and assessment (Panizzon & Pegg, 2008; Pegg, 2003). An underlying premise of the model is

> that there are 'natural' stages in the growth of learning any complex material or skill and that in certain important aspects these stages are similar to, but not identical with, the developmental stages in thinking described by Piaget and his co-workers (Biggs & Collis, 1982, p. 15).

The underlying focus of the SOLO Model is around the *quality of learning* demonstrated in a response with understanding being viewed as an individual characteristic that is both *content* and *context specific*. Importantly, it is recognised that the structure of a student's understanding may be influenced by a number of extraneous factors including motivation, intention and prior learning strategies (Panizzon, 2003).

Modes of thinking

There are two key features underpinning the SOLO model: modes of thinking and levels of complexity. The five modes are termed sensori motor, ikonic, concrete symbolic, formal, and post formal. These modes represent different, broad ways of thinking or operating, determined by the nature of the elements being employed for a task or activity.

Sensori motor mode: This mode becomes available at birth and encompasses the coordination of actions and the learning of motor skills within the physical environment. As this type of knowledge involves *knowing how* to complete a physical task, it is termed tacit knowledge. Importantly, this mode plays an important role throughout life particularly in relation to the development of sporting skills.

Ikonic mode: Accessibility to this mode occurs at about 18 months of age as actions become internalised by the individual resulting in the use and development of language and imagery. Young children in this mode use stories and mythical characters to explain human interactions while adults use the mode to assist in appreciating music, art and literature. Thinking intuitively is an everyday example of adults working within the ikonic mode.

Concrete symbolic mode: In the majority of cases this mode becomes available at around five to six years of age. It involves a major shift in abstraction as concepts and operations are applied through the symbolic systems of written language, number and musical notation. These systems require internal logic and order or *knowing what* as individuals describe their world using symbolic descriptions. It is this mode that is addressed most commonly with learning in the primary and secondary school.

Formal mode: Individuals begin to access this mode at approximately 16 years of age. Within this mode, individuals seek to understand the relationships between concepts as their thought processes become more abstract and they move beyond the need for concrete referents. Hence, they are able to question ideas, formulate their own hypotheses within specific disciplines and recognise general principles. This is considered as the highest level of abstraction required in professional practice and at an undergraduate level.

Post formal mode: Usually attained from around 20 years of age but is the most difficult to describe. It is demonstrated in postgraduate study where the conventional principles of a discipline are questioned and explored further so that the knowledge of the discipline expands. This is where individuals push the theoretical boundaries of the time. However, there is some debate about the existence of this mode.

Essentially, these modes become available in sequential order with each newly acquired mode co-existing with the earlier acquired mode. In this way prior modes continue to develop throughout life, often assisting (or perhaps impeding) developments in a later acquired mode (Watson et al., 1993). The modes and the approximate age of availability are illustrated in Figure 3. The diagram also includes four arrows (A, B, C, and D) and these refer to important pathways of development within the SOLO model highlighting different aspects of intellectual functioning (Biggs & Collis, 1991).

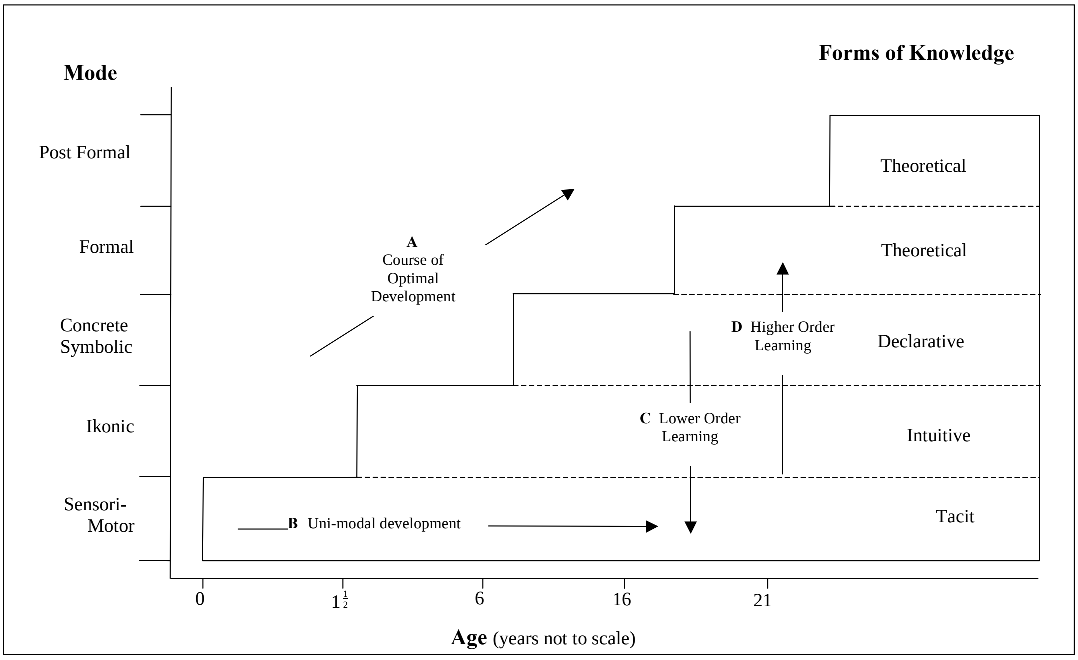

Figure 3: Modes of thinking
(Adapted from Biggs & Collis, 1991)

While these modes represent the level of abstraction at which individuals of a particular age may commonly function, in most instances we utilise these modes in a number of ways depending upon the learning context.

- Arrow A represents the *course of optimal development* assumed by theorists, such as Piaget, where an emerging stage replaces the earlier stage. The SOLO model considers that learning in earlier acquired modes supports the development of higher modes. This mirrors reality where individuals are able to access all acquired modes throughout their lifetime.
- Arrow B represents a path of unimodal functioning and represents the most straight-forward case of learning. In the case of very young children (i.e., less than 18 months) unimodal functioning is expected as only one mode is available and this is the sensori motor. The target mode for primary and secondary education is the concrete symbolic mode. However, an important issue for teachers is that when addressing learning from a purely concrete symbolic approach (i.e., ignoring characteristics of the ikonic and sensori motor modes) the subject matter can become decontextualised and hence not offer the student an appropriate developmental pathway based on the natural growth of their understanding.

In contrast, arrows C and D represent multimodal learning, which could be considered most relevant to classroom teachers. In these cases there is a target mode but teachers evoke and address other acquired modes to support student learning in their lessons.

- Arrow C is termed top-down learning as it identifies those instances when an individual uses higher-order modes to improve their performance in an earlier acquired mode. This is demonstrated when athletes working predominantly in the sensori motor mode watch videos (ikonic mode), or read books (concrete

symbolic mode) and analyse an opponent's game (Formal mode) to improve their performance.

- Arrow D is referred to as bottom-up learning as earlier acquired modes are used to support learning in a higher target mode. For example, this approach is common in science classes when students undertake investigations (involving lots of sensori motor activity), view and talk about demonstrations (illustrating the ikonic mode), come to use and explain phenomenon using science language and ideas (concrete symbolic mode) to facilitate their understanding of an abstract concept or principle within the formal mode. It is this type of learning that is supported by constructivist theory (Biggs & Moore, 1993).

Consequently, with the exception of young children working in the sensori motor mode, there are a number of modes available to an individual in any learning situation.

An appreciation of which modes can be accessed by students of different ages can help inform the implementation of a career development strategy over a broad age range. For younger children the ikonic mode lends itself to role-play activities to practise executive function skills. As they get older this mode is still accessible while the concrete symbolic mode becomes the target mode. Hence, working memory can be drawn upon and developed to help build knowledge about jobs and career awareness. As the formal mode becomes available in adolescence, young people are better able to wield effectively their knowledge of themselves and their potential careers. They can now formulate and think through scenarios in order to inform and test their decision-making.

Levels of functioning

In addition to modes, Biggs and Collis (1991) identified differences in performances within a specific mode that shared common characteristics – termed levels. These levels demonstrate a hierarchy in the learning of a task from novice to expert within each mode of functioning. The three major levels identified for any mode are: unistructural (U), multistructural (M), and relational (R). As a collective, they are referred to as *a learning cycle* (i.e., U-M-R).

- Unistructural: Indicates that the individual has understood the task but can only identify one piece of relevant information.
- Multistructural: Occurs when the individual is able to identify two or more pieces of data relevant to the task but these data are seen in isolation so that there is a lack of integration.
- Relational: Demonstrates that the learner is able to identify a number of elements that are consistent with the task and relate them to one another around a particular concept or idea.

These three levels are relevant to cognitive development in each mode. The advantage of the SOLO model is that it links these cycles of learning (i.e., U-M-R) with growth through the sensori motor, ikonic, concrete symbolic, formal and post formal modes. The interaction between modes of thinking and levels of complexity are illustrated in Figure 4.

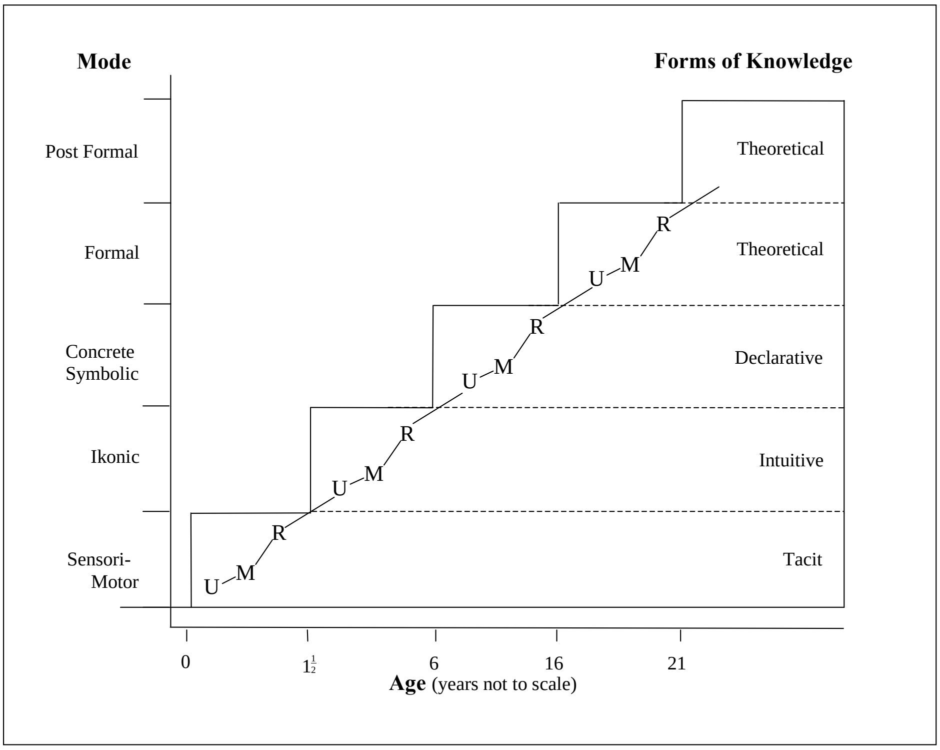

Figure 4: Learning cycles within modes of the SOLO model
(Adapted from Biggs & Collis, 1991)

Two learning cycles within a mode

Emerging from research studies across a number of school years was the realisation that a single U-M-R cycle within a mode did not accommodate the range of understanding offered by students. In particular, it was difficult to interpret responses from many primary students, low-achieving secondary students, or adults new to a particular area of study within the single learning cycle model.

As a consequence of a closer, more detailed examination of these understandings an earlier cycle of levels (i.e., a new U-M-R cycle) was identified. Importantly, the understandings coded at these levels still shared the characteristics of the same mode and so led to at least two learning cycles within each mode relevant to primary and secondary education in the concrete symbolic and formal modes (Levins & Pegg, 1994; Panizzon, 2003). These cycles are distinguished by U_1-M_1-R_1 and U_2-M_2-R_2. An attempt to illustrate this diagrammatically is provided in Figure 5.

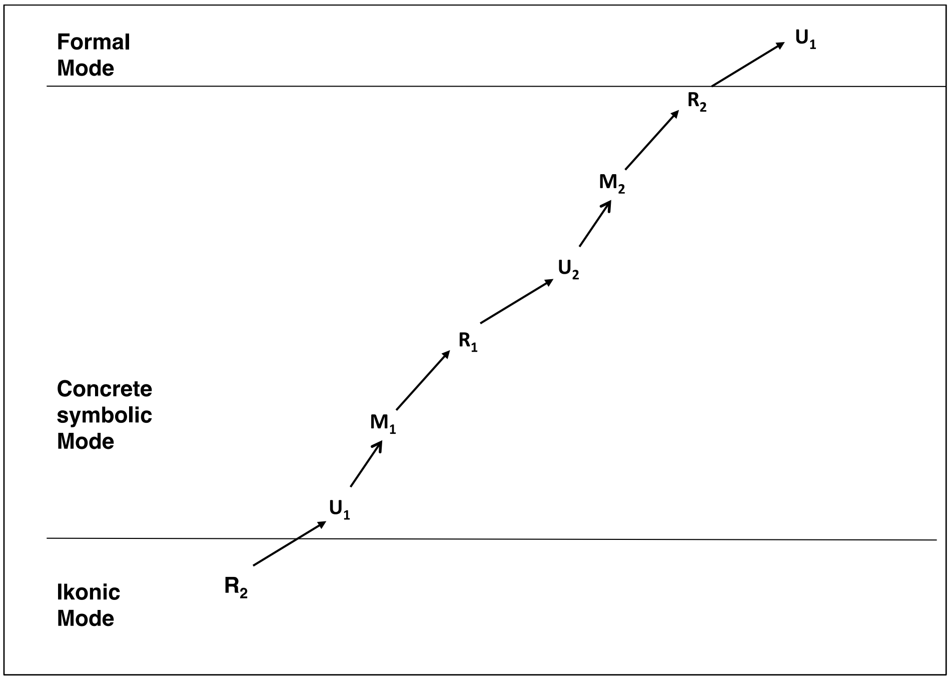

Figure 5: Two learning cycles in the concrete symbolic mode

In considering the two cycles, a U_1 response identifies one aspect or feature, the M_1 response provides two or more aspects and the R_1 demonstrating integration of aspects into a cohesive statement or 'story'. From research findings, the U_1-M_1-R_1 cycle appears to be more concerned with developing a 'global picture' of the concept being developed without depth evident. It is often very descriptive with a strong image base being influenced by the ikonic mode.

However, with time, the relationship identified at R_1 requires less working memory so that students are able to focus more closely on the more detailed aspects of the question. This leads to the second cycle in the concrete symbolic mode i.e., U_2-M_2-R_2, which involves explanations around the *cause and effect* or a focus around explaining *why* a process occurs.

It is important to recognise that one learning cycle is not better than another, it is just that one group of students are conceptually further developed for a particular concept than others at this point in time. However, given the appropriate time and experiences, the students in the U_1-M_1-R_1 cycle should progress into the next learning cycle. Similarly, just because students are operating in the U_2-M_2-R_2 cycle for one concept does not mean that their understanding will be as well developed for another concept.

While based in the realm of student learning this model and more particularly the emphasis around the modes of functioning provides a potential template for thinking about career development in schools. It aligns well with the timeline derived from the cognitive neuroscience research as summarised in Figure 2 and may resonate with educators existing understanding of Piaget. See also Part Seven below for a discussion about the use of these developmental concepts in career planning.

A detailed version of this section with educational examples is provided in Appendix 1.

Part Five

Helping young people to improve their decision-making

Many of the early programs and strategies that have been used to help improve young people's executive functions were developed for young people with identified challenges or diagnosed disorders such as deficits in attentional capacity. More recently, interventions to support executive function development for a more general population have been put in place and from these experiences some broad principles can be drawn (Diamond & Lee, 2011):

(i) *Those young people with the initially poorest executive functions gain the most.* Contrary to the idea that levels of inhibitory control, working memory, and cognitive flexibility are somehow innate or genetically predestined, young people who start from a lower base gain most from targeted support. This has the effect of levelling the playing field in terms of the cognitive skills required for decision-making and career planning. For example, children from lower socio-economic status backgrounds tend to have lower levels of executive functions but support will likely help them the most.
[See recommendation #1, page 39]

(ii) *Largest differences on most demanding executive function measures.* Differences between young people (as groups or individuals) are particularly apparent as tasks become more difficult and greater demands are placed on executive functioning. "Everyone does fine when executive function demands are low" (Diamond & Lee, 2011) but "Perhaps the pinnacle of executive functioning is the ability to plan" (Best *et al.*, 2009). Low-level tasks will not differentiate between young people or help identify those who will likely be challenged by all but the simplest decision-making and career planning.
[See recommendation #2, page 39]

(iii) *Executive functions must be continually challenged*. In programs that successfully develop executive function skills the difficulty of the tasks (and thus the cognitive demand) increases. Less successful programs have young people practising tasks of similar difficulty and little improvement is seen. Decision-making and career planning can be demanding of executive functions and so the more a student can be stretched to develop ever better executive functions the higher the quality of their decisions will likely be.
[See recommendation #2, page 39]

(iv) *Executive functions can be improved by educators (with professional learning and support).* This important finding indicates that the skills that underpin effective decision-making and career planning can be developed in existing learning environments, with existing staff (e.g., teachers, career advisors, classroom assistants). It has been demonstrated that with appropriate professional learning all educators can play a significant role in improving cognitive outcomes for young people. Investing in the skills of educators builds capacity within schools whereas commercial resources can foster dependence on continually buying in unnecessary resources and expertise.
[See recommendation #3, page 39]

(v) *The benefits of exercise and in particular martial arts.*
Aerobic exercise (increasing in difficulty over time) improves cognitive flexibility and creativity but not non-executive function skills. It shows a doseresponse meaning that to some extent more exercise leads to higher levels of executive functioning, though only on the more demanding cognitive tasks. Daily exercise for thirty minutes has been shown to improve executive functioning in thirteen to fourteen year olds but five-minute movement breaks do not (Kubesch et al., 2009). Evidence of the benefits of sport is not available but it is reasonable to predict that sports that demand high levels of impulse inhibition, working memory and cognitive flexibility may develop these in participants. Studies of children learning traditional martial arts such tae-kwondo that emphasise discipline and mindfulness have shown improvements across a range of executive function skills. In one study with clear implications for career planning, each martial arts session began by participants asking themselves "Where am I?", "What am I doing?" and "What should I be doing?" These questions were designed to give the children the opportunity to practise selecting behaviours, comparing their behaviour to their goal, and making plans for improvement. Other mindful practices such as meditation and yoga show increases in executive functions (when cognitive demand is high) in comparison to physical training and modern, competitive martial arts that do not.
[See recommendation #4, page 39]

(vi) *Use of technology and "brain training".*
There is accumulating evidence that video games enhance some cognitive skills (e.g., Howard-Jones *et al.,* 2010). For example, certain aspects of attentional capacity are greater among gamers who play games that demand high attentional capacity (the game Medal of Honour) compared to those that do not (Tetris) (Green & Bavelier, 2003). Similarly, video gaming laparoscopic surgeons make fewer errors than their non-gaming colleagues when their surgical skills were evaluated (Rosser *et al.,* 2007). So-called *brain training* products have failed to produce convincing evidence to back up their claims about cognitive skill development. On the whole any improvement in performance is limited to the training itself and do not transfer to everyday thinking (Owen, 2010). Despite these disappointments, one aspect of executive function training does stand out. A range of studies have shown that working memory can be improved by computer-based training (Klingberg, (2010) and these improvements are mirrored by changes in the activation of regions of the brain associated with working memory (Olesen, *et al.,* 2004). Studies have also shown that processes dependent upon working memory, such as the ability to solve problems in new situations, are also improved after training (Jaeggi, *et al.,* 2008).
[See recommendation #5, page 39]

(vii) *Transferability of gains in executive functions*
So far, most interventions aimed at improving executive functions have each focused upon a specific aspect (e.g. inhibitory control, working memory or cognitive flexibility). As with computer-based brain training, it is generally the case that while supporting a young person to develop a single aspect can be successful it appears not to transfer into other executive functions. For example, successfully developing working memory skills does not transfer into

improvements in cognitive flexibility. Gains in executive functions through active participation in traditional martial arts or through a strategic shifting of focus within a school may be broader because of the broader nature of the programs themselves and the range of executive functions that are demanded in the programs.
[See recommendation #6, page 40]

(viii) *Practice and a broad approach to developing executive functions*.
Executive functions are exercised in a range of day-to-day experiences and many activities that demand a high level of executive functioning will develop those skills in young people who practise them. Games, classroom activities and "executive function snacks", as one education professional described them, can go some way to sharpening particular skills but a broader approach will "need to address executive functions throughout the day, not only in a module. Repeated practice produces benefits. Even the best activity for improving executive functions done rarely produces little benefit" (Diamond & Lee, 2011). There is a need for sustained development of the skills that underpin decision-making and career planning, coupled to the trajectory of executive function development. The information summarised in Figure 2 makes the case for a career development strategy that builds foundations in the early years upon which further development is built throughout childhood, adolescence and early adulthood.
[See recommendation #6, page 40]

(ix) *Importance of wellbeing in executive function use and development.*
As with so many aspects of young people's lives and their learning, wellbeing plays a crucial role in executive function use and development. Executive functions are impaired by stress (Arnsten, 1998), loneliness (Cacioppo & Patrick, 2008) and a lack of physical fitness (Hillman *et al.*, 2008)) (mirrored by differences in brain activity in regions responsible for executive functioning). It is interesting to recall in this regard the difference between the positive impact upon executive functions of traditional martial arts (that focus upon discipline and self-control) compared to modern competitive martial arts (that focus upon skill development and competitive fighting) that have no positive effect on executive functions. In mathematics education, students can be trapped in a downward cycle in which "maths-anxiety" has a negative impact upon their working memory. Mathematics performance depends heavily on working memory for all but the simplest recall tasks and so the negative impact of *maths-anxiety* on working memory consequently drives down performance. This drop in performance may cause more anxiety and so the cycle continues (Ashcraft & Krause, 2007). Again, as tasks increase in difficulty, lower levels of working memory become much more apparent, (Ashcraft & Kirk, 2001) effectively limiting those *maths-anxious* students to lower-level cognitive function and lower-level mathematics performance.

> High math anxiety works much like a dual task setting: Preoccupation with one's math fears and anxieties functions like a resource-demanding secondary task (Ashcraft & Krause, 2007).

That is, young people dealing with chronic stress, anxiety or worries can divert so many cognitive reserves to dealing with these challenges that it has a clear and demonstrable negative effect upon their executive functioning and so their

ability to learn, make decisions and plan. As a consequence, such challenges to wellbeing confine young people's thinking into the moment making it difficult for them to use their stop-and-think skills to be future-oriented and plan effectively. When the cognitively demanding tasks are required such as those involved in making decisions about career futures these young people will need particular support in the development and use of their executive function skills with special attention to creating a safe learning environment.
[See recommendation #7, page 40]

(x) *Appropriate expectations.* It is important to approach the development of executive functions with appropriate expectations. As mentioned above in *(iii),* understanding the level at which individuals are operating and making the tasks increasingly cognitively demanding is necessary. Similarly, not having unduly high expectations is important. When placed in a learning or work environment where demand on an individual's executive function skills outstrips their capacity, they are unlikely to succeed; stress increases, self-confidence diminishes and executive functions are diverted away from the task at hand. Young people placed in these situations may withdraw and hide their difficulties through other behaviours. In exhibiting these responses it may seem to observers that the students are giving up, showing a lack of effort, and are behaving in disruptive or other inappropriate ways. For young people with lower levels of executive function, decision-making and planning tasks should not take place in a context that demands high levels of executive functioning. For example, requiring young children to sit still for long periods of time diverts their limited capacity to inhibit impulses away from the task at hand such that any the cognitive demand to carry out the task will not be met. Considering where students are in their development of executive functions and responding accordingly by making sure that the decision-making and planning they are asked to do is stretching but not overwhelming them will likely achieve the best outcomes.
[See recommendation #2, page 39]

These ten general principles can be used when designing any interventions to develop young people's decision-making skills and their ability to escape from the moment, plan for their futures and appropriately stick to, or modify, those plans.

There are also a number of core elements common to several successful interventions designed to improve executive functions:

Firstly, a **strategic shift** occurs in which development of executive functions and decision-making skills is fostered within the existing curriculum (Diamond, Meltzer, Gathercole). Study skills programs included in a large meta-analysis (Hattie *et al.,* 1996) showed that those separate from the curriculum "did not seem very effective". Keeping the intervention within the curriculum allows educators and career advisers to take what is already being done in schools and shift the emphasis to include more executive functioning. For example, students will sometimes do worksheets or problems that are over-scaffolded and broken down into such small chunks that "what we're doing here is taking a compelling question, a compelling answer but we're paving a smooth straight path from one to the other and congratulating our students for how well they can step over the small cracks in the way". The same approach to a compelling problem can be used to build understanding within the curriculum and

also develop executive function if the students are asked to think about how they would go about formulating the problem and solving it. The Australian Curriculum (2011) provides opportunities and a mandate for this sort of shift to take place. For example, in the Year 9 science curriculum, elements of the *Science Inquiry Skills* strand require that students can “formulate questions or hypotheses that can be investigated scientifically” and “plan, select and use appropriate investigation methods…”. The extent to which students are led through this process or supported to practise their decision-making and planning skills will depend upon the approaches taken by individual teachers. Career advisers can play a similar role in adapting any existing resources and activities that let students “step over the small cracks” in a linear predefined process into an open-ended engagement with a “compelling problem” (e.g., through scenario-based problem-solving approaches).
[See recommendation #6, page 40]

This leads to the second element, the opportunities for students to **practise** their developing skills, and the provision of sufficient time for them to do so. As outlined above, executive function development is crucially dependent upon practice. Games and activities targeted at improving particular aspects of executive functions can be helpful but more holistic approaches are likely to be more authentic and engaging especially for older children and adolescents. Problem solving activities in which planning, prioritising and decision-making are required will demand a range of executive functions working together and so provide the practice needed in a way that is more likely to transfer. Teachers and career advisers can use scenario-based problem-solving and decision-making activities (e.g. in which recommendations are made and critiqued) in school. Similarly, parents can hand over age-appropriate planning and decision-making responsibilities to their children whether it is by asking young children to navigate the drive to a familiar place, or teenagers to plan arrangements for a family holiday. Day-to-day activities like these can provide frequent and rich opportunities for practice in using executive functions.
[See recommendation #6, page 40]

In all of these activities, the third element of **scaffolding** to support young people as their executive function improves is required. Some students seem to use their executive function processes independently but for others more support to take each small developmental step is required. Teaching of strategies can help and clearly communicating the purpose and importance of each strategy is required if young people are to understand how to employ them effectively. For example “This will help you to decide what is most important to you” or “This will help you to organise your thoughts”.

> Planning… is an important executive function process that is not taught systematically in schools even though it is a prerequisite for reading, writing and completing projects. Students are not usually taught to set short- and long-term goals that guide their approach to homework, studying and test taking. Many students… may begin tasks impulsively with no plan of action. This often results in their “getting stuck” when the next step is unclear and in an end product that is disorganised and incoherent. (Meltzer, 2007)

Teachers, career advisers and parents can use everyday occurrences to scaffold processes dependent upon executive functions such as planning (inhibiting the impulse to dive into the task). In a recent review of the scientific evidence of executive function interventions for primary school children (Diamond & Lee, 2011) six approaches were identified and planning by children was a component of the majority of programs. A vital component of scaffolding in this way is the quality of the **constructive feedback** given to young people to give guidance on how they might shape and modify their behaviour, and also for them to see the **value** in doing so.
[See recommendation #8, page 40]

Just as scaffolding is important in the early stages of young people's skill development so the gradual **removal of the scaffolding** is required as their skills improve. If the scaffolding and support structures all remain in place even when the individual is quite capable of dealing with the task independently then their development may be held back. As discussed above, it is important that the difficulty of tasks increases so as to give the student the opportunity to further develop their skills. Slowly dismantling the scaffolding also allows young people the opportunity to develop their own strategies that can be generalised and transferred. Creating an environment and a culture in which young people are encouraged to "give it a go" themselves and are willing to do so untethers them from the support structures upon which they should decreasingly depend.
[See recommendation #8, page 40]

Teachers, career advisers and parents can **model the use of executive functions** and the strategies used to support them. Making daily schedules, using calendars and setting agendas are simple ways of modelling planning processes. Other day-to-day uses of executive functions and strategies to support them may be employed by adults but are sometimes not apparent to young people and may need explicitly pointing out. For example, time management and household budgeting may not be activities in which young people are usually involved but create opportunities for modelling executive functions. It may be beneficial to explain to an adolescent the thinking behind decisions and plans, the way in which weight is attached to the pros and cons of a situation, and the consideration of the risks and potential future consequences of a decision. Revealing these processes, and even asking a teenagers advice, gives them the opportunity to see how they can be used and to **value** them.

Most suggested interventions use **organisers, memory aids** or **tangible reminders** in some way. Many of these homework planning sheets, shopping lists, task templates, etc., are well known devices as study aids, even if the development of executive functions is not their primary purpose. The *Tools of the Mind* program (Diamond *et al.*, 2007; Bodrova & Leong, 2007) uses reminders in a slightly different way (as a Vygotskian mediator). Despite this being a preschool program, the use of physical objects to help children practise their executive functioning may effectively transfer into primary and secondary school environments. For example, *Tools of the Mind* exploits a common practice of "buddy reading" in which one child will read a book to their friend: Buddy reading carries on as usual but a strategic shift is employed so that the listener uses the opportunity to practise inhibiting the impulse to say something and interrupt the story. This can be particularly difficult at moments of high drama in the narrative. To assist the child to not interrupt and to inhibit that impulse, they are given a picture of an ear. Grasping the picture whilst listening serves as a reminder

and helps the child to hold the idea of their role in their working memory, appropriately directing and sustaining their attention in line with that role and to inhibit any impulsive responses. Older children and adolescents may benefit from similar support. For example, teens who exhibit impulsive behaviours may find it useful to have a tangible reminder to hold as they try and inhibit a particular impulse, perhaps around managing a violent outburst or a risky behaviour. In this way, a tangible object can act as an agent to support the transfer of executive function skills being developed in the classroom or at home to situations where an adolescent is away from their support structures and people, whether that be in social environments or a workplace.
[See recommendation #8, page 40]

The final core element of successful implementation of interventions is the need for **professional learning** for teachers, career advisers and classroom assistants. Parents may also benefit from some appropriate learning. The sophisticated incorporation of the evidence base, and the principles and elements briefly described here into any strategy will depend upon the professional learning of educators.
[See recommendation #3, page 39]

The principles and elements described above are relevant for the development of executive function skills. However, there is some evidence suggesting that executive functions can be resistant to change (e.g., Engle *et al.*, 2008, Casey *et al.*, 2011) and in any case career advisers and other educators may find themselves in circumstances where they have little influence over the ongoing experiences of the young people that may shape their executive function development. In these situations it is important to **support the decision-making itself** if young people do not have the underlying skills to effectively do so themselves.

As described in the "Freedom's Orphans" report by the UK's Institute for Public Policy Research (Margo *et al.*, 2006):

> … as opportunities opened up for [individuals] reaching adolescence between 1960 and 2000, young people's agency became more important in determining their outcomes throughout life, in education, in work and in their communities.
>
> These developments affected the disadvantaged in particular. Life course events that were once normatively structured by 'traditional' institutions (…clear, if oppressive, career paths), were increasingly left to individuals to decide on their own, leaving them to take on new responsibilities for living with the consequences of their actions.
>
> For those with the capacity to take advantage of these changes, typically the affluent, expanding opportunities led to improved outcomes. But for those without, events left them further behind than ever.

Appropriately supporting the decision-making of young people with their different levels of decision-making skills does not necessarily mean a return to those traditional institutions or the "clear, if oppressive, career paths". When they are aware of the executive functioning capabilities of young people with whom they are working career advisers, teachers and parents can put in place strategies to reduce the demand on inhibitory control, working memory and cognitive flexibility.

As exemplified above with the example of maths anxiety (pg 22), the immediate external factors, including their emotional state can eat into young people's reserves of executive functions. If they are asked to reflect on their aspirations, the career-related information they have been given, and then bring it all together to make meaningful decisions and career-plan, external demands on executive functions should be removed or minimised. For example, in busy classrooms, where there are many distractions, some young people will not have sufficient inhibitory control to hold the distractions at bay while they go through the decision-making process. In the medium term, the goal might be to improve that inhibitory control but in the short term the teacher may need to respond to the immediate (executive function) needs of the student. That is not to say that classrooms should be bland, unstimulating and silent places but that the educator creates the characteristics of the learning environment that appropriately support the task at hand.

Some of the elements that support the development of executive function skills can also be used to support executive functioning in the decision-making process. Most notably, the use of scaffolding (with constructive feedback and a shared sense of the value of the process) and in the use of organisers, memory aids, and tangible reminders can be used to support decision-making.

In scaffolding the decision-making process, adults such as career advisers are essentially using their own executive function skills as a surrogate for those of the young person. In this role, they are not making the decisions for the student nor are they necessarily advising them on the path to take. Rather, they might use their own working memory to bring into consideration information about a job or industry that the student has encountered before but is not bearing in mind during decision-making. The adult's working memory and inhibitory control might be leant upon during a planning process to keep in mind the goal toward which the plan is working and to keep the planning process on track. When the plan is underway, the adult's cognitive flexibility and working memory might be used to help the student take stock of how the plan is going (toward the set goal) and to stop and think about whether the goal, or aspects of the plan, are still appropriate or need revising in the light of unfolding events. This may not be drastically different from the practice of many career advisers but a greater emphasis on the process of decision-making rather than the decision itself may represent a **strategic shift** for some.

Breaking down a decision-making process into bite-sized chunks can reduce the working memory load in that only a few ideas need to be held in mind at any one time. Similarly, using pen-and-paper or electronic resources to capture information about the young person's aspirations, jobs they have investigated, education options they have considered, etc., can help prevent young people from becoming overwhelmed. An approach to (mathematical) problem solving that has been successfully used for over fifty years (Polya, 1945) and continues to be in print, that starts with four principles: understand the problem; make a plan; carry out the plan; review. In the QuickSmart program developed at the University of New England this process has been adapted to incorporate more scaffolding in the understanding and planning phases (Pegg, 2011). This approach has become known as the 6Ss:

1. SEARCH (... for information)
2. SORT (… which information is relevant and prioritise the information)
3. SEE: (visualise the problem – try to get an overview)
4. SELECT: (… the processes that will be used to solve the problem)
5. SOLVE: (use existing and new knowledge to address the problem)
6. SENSE: (reflect on the outcome – does the answer make sense?)

The final two steps (solve and sense) are the same as Polya's "carry out" and "review" but the first four steps encourage students to use their stop-and-think skills before diving into the problem. It supports them to inhibit the impulse to start out without direction, to use their working memory and cognitive flexibility to break down the available information into manageable parts but then to return to the problem (or goal) that is targets. A purposeful selection of the route to be taken takes place and only then is the problem directly tackled. Scaffolding in this way applies equally well to students who need support in decision-making and career planning (see example on page 36).

There are many ways in which executive functioning in the classroom can be supported (see for example Kaufman, 2010, Dawson & Guare, 2010, Meltzer, 2009, Gathercole & Packiam-Alloway, 2008, McCloskey *et al.*, 2008) most of which can be adapted to an individual student's needs in decision-making and planning. Many of the available resources include sheets that can be photocopied and other processes that can be directly reproduced in the classroom. While this offer may seem initially attractive, it can suffer from being over simplistic. Worksheets and generic resources are likely to be insufficient for the demanding and diverse requirements of young people's decision-making and career planning. They serve to allow students to go through the motions without actually engaging with the process and limit those students who have more developed executive functioning skills. For these students with greater decision-making capabilities, even those processes of breaking down decision-making into bite-sized chunks can have a negative effect in that it pushes student responses into unistructural and multistructural levels (see Part Four) away from more sophisticated relational approaches where they can see and exploit the interactions between the steps in the decision-making process. To use these resources effectively and to be able to purposefully adapt them to the needs of the students in their classrooms, career advisers and teachers will need appropriate professional learning to complement their existing experience and expertise (Diamond & Lee, 2011).
[See recommendation #9, page 40]

Part Six

Cognitive neuroscience and the barriers being raised to career development

Neuromyths

Research findings in cognitive neuroscience are increasingly used in providing evidence to inform policy and practice in education, but they also become open to misuse. Commercial organisations, education consultants and systems themselves are sometimes guilty of over-interpreting or misinterpreting research findings to push particular approaches to teaching and learning. This improper interpretation of the evidence has led to a collection of so-called *neuromyths*. For example, it is a commonly held view that individuals "only use 10% of their brains." Similarly, adults who are supporting young people in making decisions about career pathways are still being sold the idea that individuals can be identified as left-brain or right-brain thinkers. These ideas are inconsistent with modern neuroscience and only serve to limit young people, their view of their own potential and the decisions they make (Geake, 2008; Goswami, 2006; Lindell & Kidd, 2011).

Most worryingly, *neuromyths* are sometimes used to direct choices and funnel young people into particular career pathways. It is important for young people to be aware of their strengths and weaknesses and then weigh those against the pros and cons of potential career pathways (though see Figure 2, page 10 comments about changes in the nature of the strategies they use) and the educational opportunities available to them. However, this can be simplified into profiling students based on the idea that they are predominantly left-brain thinkers or right-brain thinkers, a practice for which there is no modern scientific evidence (Howard-Jones, 2009; Lindell & Kidd, 2011). Similarly, baseless ideas around preferred learning styles are used to categorise young people in terms of the kind of learner that they are. Many of these inventories will claim or suggest that they are based in neuroscientific research evidence but this is not true for most, if not all of the current approaches that define learning styles. Making such claims increases their appeal to educators (Weisberg et al., 2008). At best the idea that young people have a preferred learning style is unhelpful in itself (Coffield *et al*, 2004a; Sharp *et al.,* 2008) due to a range of impacts arising from the way that learning styles in practice suffer from "labelling, vested interests and overblown claims" (Coffield *et al*, 2004b). Career development advice can be particularly sensitive to these forms of categorisation in which there is often "unwarranted faith placed in simple inventories" (Coffield *et al*, 2004b). For example, one inventory that is used quite widely in Australia categorises young people as either Visual, Auditory or Kinaesthetic learners (thus referred to as VAK learning styles) though it has no neuroscientific or other theoretical basis (Geake, 2008; Goswami, 2006; Sharp *et al.,* 2008) and is inconsistent with the SOLO framework (Biggs & Collis 1982, Biggs & Collis, 1991). The danger is that the VAK learning styles inventory is used to tell young people what kind of learner they are and therefore which education and career pathways are open to them and which are closed. A more sophisticated future oriented approach considers the aspirations of the individual, their current strengths and weaknesses and identifies areas for focused improvement and further education in order to meet those career goals. This kind of approach to personal development is in stark contrast to considering characteristics to be fixed therefore closing down opportunities. An extreme example of advice of this kind would be, "you're not a kinaesthetic learner so you shouldn't consider a job where you need to use your hands".

Categorisation

Any form of categorisation of young people can limit their outcomes. Whether it be a *neuromyth,* purposeless ability-grouping at school, or reminding young people about their ethnic origin, sex, or the community from which they originate. Reinforcing a pre-judgement of themselves can impact young people's view of themselves and ultimately the decisions they make (Ireson & Hallam, 2009). In particular, young people's view of their own intelligence or whether they see themselves as effective learners can profoundly change the emotional and cognitive contexts in which decision-making takes place (Blackwell, *et al.,* 2007; Nussbaum & Dweck, 2008). Increasingly, research indicates that the ways in which young people categorise themselves is directly influenced by the signals they receive from adults around them both in the long term and at the moment of decision-making (Murphy & Dweck, 2010). By strategically modifying the cues and signals young people receive, they can be supported to make higher quality decisions.

In one study (Nussbaum & Dweck, 2008), undergraduate engineering students were given a four-module test and they were told that it was predictive of academic performance, and successful engineers did well on all four parts.

> The test actually consisted of spatial-reasoning exercises from the dental admissions test administered to prospective students of dentistry. These tests were particularly useful for our purposes because it was difficult to determine whether one had answered correctly or incorrectly with any degree of certainty, making both high and low scores plausible. One of the tests, for instance, required participants to rank four similar angles in order of acuteness (Nussbaum & Dweck, 2008).

Regardless of how the students actually performed they were all told that they scored five out of five on three of the modules but only two out of five on a fourth.

> Participants were told that as a part of the study they would have the opportunity to do a tutorial for only one of the four modules. After completing the tutorial of their choosing, they would be given another test on the material specific to the module they had chosen. They were also told that they would receive a certificate that would indicate their score on the post-tutorial test. Thus, participants could choose either a tutorial on one of three already mastered modules, which would assure them of a certificate with a high score but would teach them little, or they could choose the tutorial on the failed module, which did not guarantee success, but provided them with an opportunity to improve (Nussbaum & Dweck, 2008).

All of the students chose to participate in a tutorial.

Immediately before the test the students were given what was ostensibly a reading comprehension test but participants were randomly assigned one of two documents. Around half of the group read that intelligence cannot be changed (the entity theory of intelligence) with statements like "current research shows that almost all of a person's intelligence is either inherited or determined at a very young age". The other half read that intelligence can be improved and developed (incremental theory of intelligence) for example, "current research shows that intelligence can be increased substantially".

While all the students chose a tutorial and to retake the test in that module, of the group that read the document emphasising that intelligence can be developed 91% chose the tutorial in which they had received a mark of two out of five. The other group that were essentially told to *know how smart you are and deal with it,* only 53% chose the module in which they had received a low mark. Almost half of this group chose to go through a tutorial and retake the test in a module in which they had already scored full marks.

This study serves to exemplify a body of research that highlights the difference between students who focus on their performance levels and having a view of their intelligence as being somehow fixed compared to those who focus on their learning and think of their intelligence as being something that can be developed. The former group tends to have a flat or downwards trajectories in terms of school grades (regardless of their actual performance level) while the latter tends to have an upward trajectory on their grades (i.e., grades increasing over time) (Ireson & Hallam, 2009, Blackwell, *et al.,* 2007; Nussbaum & Dweck, 2008, Murphy & Dweck, 2010).

Students with a view that their intelligence is fixed tend to focus on their performance but when they encounter a problem or difficulty they either withdraw (*I'm not smart enough for this*) or continue to apply a mechanism that they have been taught even though it fails repeatedly. Students who see their intelligence as something that can be developed, focus on their learning, distance-travelled and skill acquisition. When these students get stuck they look for input from teachers, parents or their peers; they will look for an alternative way to address the problem or consider what skills they will need to acquire to overcome it (Blackwell, *et al.,* 2007).

As illustrated with the engineering students, this sort of self-categorisation profoundly affects the day-to-day decision-making of young people and ultimately their academic outcomes. Ironically, this research suggests that students who focus on their performance will actually perform less well than students who focus on themselves as learners (all other things being equal) (Blackwell, *et al.,* 2007).

Importantly for career advisers, teachers and parents evidence suggests that it is the characteristics of the environment that is created around a young person that shapes their view of their intelligence and that of themselves as a learner (Murphy & Dweck, 2010). The characteristics that are valued within an organisation are reflected back by the individuals operating within it. That is, if a student finds themselves in a classroom in which performance is valued, they will shift to see themselves as having a fixed intelligence. Students who see themselves as effective learners and focus upon developing their intelligence are more likely to emerge from a classroom that values learning and intellectual growth.

Other forms of categorisation: sex, gender and ethnicity

There is a paucity of research in the area of inherent differences in decision-making skills (including executive functions) due to ethnicity. Any differences that do exist between ethnic groups including Australians of Aboriginal or European origins are likely to arise from cultural differences and socialisation. (e.g., Dingwall & Cairney, 2010, Han & Northoff, 2008) There is little or no evidence to suggest that

fundamental differences exist between individuals of different ethnic backgrounds in terms of executive functioning, other than from their different experiences.

There are broad differences between male and female cognition, including in executive functioning, but again the balance between nature (genetic factors) and nurture (environmental factors) is uncertain and the subject of body of existing and ongoing research. For example, a recent study (Beltz *et al.,* 2011) sought to investigate the impact on career choices of a genetic condition that exposes babies in the womb to higher than normal levels of testosterone and other hormones (androgens) that lead to male characteristics. They listed jobs as pertaining to either "things" or "people" and in unaffected individuals identified that males had a bias toward the "things" jobs and females to the "people" jobs. The females who had been exposed to high levels of testosterone were more likely to choose "things" oriented jobs than the females who were not exposed. Moreover, the more testosterone they were exposed to in the womb, the more likely the females were to prefer "things". As the authors noted:

> Our findings indicate that career choices are influenced by prenatal androgens through a psychological orientation to objects versus people that manifests in gender-typed occupational interests. We emphasize, however, the complexity of career choices: occupational interests are not determined exclusively by sex or prenatal androgen exposure, as seen in the overlapping scores of our groups, and in other data showing parent socialization of occupational interests (Eccles, 1994); moreover, interests are only one contributor to career choice (Halpern et al., 2007). In combination with other findings on gendered interests, our results are relevant to efforts to increase participation of girls and women in STEM [science, technology, engineering and mathematics] careers. It is important to recognize that career choices have roots in early-developing and biologically-influenced interests. Girls and women might be encouraged to pursue STEM careers by focusing on the ways in which an orientation to people is compatible with those careers.

Even where differences in cognition do exist between groups due to sex, gender, ethnicity etc., whether genetically or culturally determined, there is usually overlap between the groups. On average, there may be statistically significant differences but if the ranges overlap then these generalisations cannot be applied to individuals. The danger of doing this is the reinforcement of unfounded stereotypes and selfcategorisation such as: "boys can't do those jobs", and "kids like me aren't smart enough to do that." Paradoxically, this is one of the pitfalls of running a campaign to attract under represented groups to particular areas of the workforce (e.g. females to engineering careers). In this example, the campaign messages can serve first and foremost to remind females of their sex (and the associated stereotypes and social implications) rather than promote a self-view that they are a potential future engineer. **[See recommendation #10, page 40]**

Part Seven

A timeline for interventions

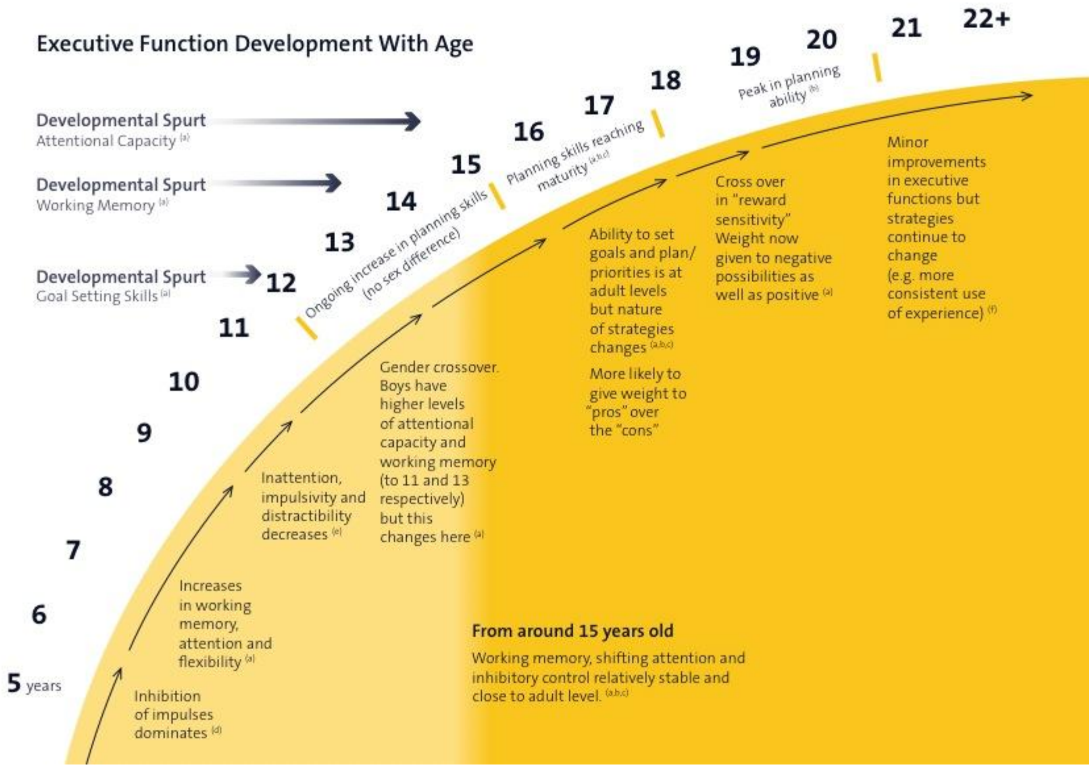

Figure 2: Executive function development with age
The timeline gives a broad indication of the development of executive functions with age (full size figure on page 10)

Figure 2 (reproduced here for reference) suggests some general age ranges at which career planning interventions might be made. Ideally, consideration should be given to the level of development of executive functions of individual children but for policy purposes, especially in considering at what age different interventions might be made, this loose association between executive function development and age may be useful.

Activities and interventions aimed at children aged **five to ten years old** should give them the opportunities to practise their executive function skills. Inhibitory control, working memory and cognitive flexibility may be individually addressed through games and other training-style activities. More success is likely to be achieved through a broader strategic shift where executive function development becomes a focus across a broad range of activities already undertaken within existing curricula (including the Australian Curriculum). The case has been made above that the development of these skills in childhood is important not just for decision-making but as a necessary condition for success in later life measured by a range of outcomes. Decision-making skills are likely to be developed through activities that help students practise their ability to stop-and-think, to consider the information available to them, to prioritise and weigh the evidence, to make a decision or form an opinion and then modify that decision over time. One such approach is the "Community of Inquiry" process developed by Matthew Lipman as part of the "Philosophy for Children"

movement, and already used by a number of schools in Australia from pre-school to year 11 (Lipman, 2003, Lipman *et al.*, 1980). Through the *Community of Inquiry,* children typically discuss with their peers their responses to an idea, some text, a video, etc.

> Discussion in the community of inquiry is not just a process of swapping opinions. Classroom discussion is aimed at the construction of the best answer to the questions raised. This best answer is not provided or validated by the teacher. Instead, the class has the responsibility for both constructing and evaluating the range of possible responses to a question. Philosophy for children is not based on the assumption that there are no right or wrong answers. Instead, it is based on the belief that, even if final answers are difficult to come by, some answers can reasonably be judged better - more defensible - than others.
>
> Philosophy for Children emphasizes a conversation and dialogue based process of inquiry. As all participants share their own ideas so each individual must consider many different perspectives. Many students have the experience of seeing that what they thought was obvious is not obvious to people who have different perspectives. This encourages tolerance of others ideas, and increases students ability to work together (Burgh, 2006).

The *Community of Inquiry* process serves as an example of an intervention to support executive function and decision-making development that is not prescriptive, simplistic or subject to a particular algorithm. The mechanisms that do exist support children to inhibit jumping into the discussion immediately and to hold on to a thought and develop it. They are encouraged to respond to other children's contributions to the discussion in respectful ways and to offer reasons why they have made a particular point or response. Just as in decision-making and career planning there is a large degree of indeterminacy in this process which teachers and students can initially find difficult. There is no right answer from a *Community of Inquiry* approach and certainly no possibility to check "in the back of the book" afterwards. Importantly, every child's contribution is valued (creating an environment in which children feel safe to offer some input) but as the group considers responses to a question they are considering the quality of those responses and their reasons for their conclusions. Using processes like the *Community of Inquiry* gives children the opportunity to practise and develop their executive function skills in their decision-making and to see the processes being modeled by their peers. Such processes give the educators involved an insight into the inhibitory control, working memory and cognitive flexibility of children that might otherwise be difficult to see through other classroom activities.

The *Community of Inquiry* approach can develop generic decision-making skills but may also be a valuable tool in career planning and development. That is, while the process of *Community of Inquiry* develops the skills, the specific material being considered in any session may be directly relevant to career planning. For example, a recent *Community of Inquiry* undertaken by Year 7 students at a school in a coastal location in South Australia discussed marine parks which included a consideration of the jobs dependent upon access to the sea and the ways in which marine–related employment is likely to change in the future.

In addition to developing the skills that underpin decision-making of children emphasis should be given to their view of themselves as effective participants in future education and employment with something to gain from education and training. If students do not see themselves in this way there is a danger that they will go through the motions of decision-making and career planning without actively engaging in the process or deriving any benefit from it. These activities should also help children to see opportunities beyond their immediate environment and existing experiences, including a consideration of emerging and as yet unknown opportunities. As described above, it has been demonstrated that the way in which young people see themselves can be changed and a shift from focusing on their performance (entity view of intelligence) to their learning (incremental view of intelligence) will in turn lead to improved academic outcomes (Blackwell, *et al.*, 2007). In career development it is important for young people to be, and to see themselves as, effective learners who can shift into new environments and learn how to be effective within them. Without this self-concept children may start to limit themselves to considering only those career pathways that are likely to take them to familiar places or pathways that require the least effort (e.g. in terms of future learning or moving away from the familiar comfort of a peer group).

Executive functioning, decision-making and planning are particularly required when operating in unfamiliar situations. New experiences often come with a degree of risk and being able to apply some stop-and-think skills to risky situations and planning through them is notoriously difficult for children and adolescents (see above, page 3) (Adams, 1995, Romer *et al.*, 2011). The lack of risk education in schools and homes has been the subject of much commentary (e.g. Tierney, 2011). Young people are not well prepared to think about the risks involved in following particular career pathways though they are often well aware of the benefits (see Figure 2). For a range of reasons it is difficult for schools to allow students to practise risk-taking, but parents are well placed to provide safe environments in which children can actually mitigate the risks by planning, practising and thinking about precautions. For example, Gever Tulley from the Tinkering School has created a handbook for parents "Fifty dangerous things (you should let your children do)" (Tulley & Spiegler, 2009).

The development of the executive functions occurs at a slower rate in **eleven to fifteen year olds.** However, a series of cognitive "growth spurts" during these years push young people toward adult levels of executive functioning.

As impulsivity and distractibility decreases, this period may be best suited to developing the planning skills of young people and laying the foundations stones of experience and knowledge upon which they will build future decisions.

Work experience can provide some of these experiences and in addition, a strategic shift in the purpose of work experience can be introduced. The choice of work experience placements creates an opportunity to practise the skills required when choosing steps along a career pathway. For example, the 6Ss of the QuickSmart approach to problem solving can be adapted to making the decision. As discussed above (page 27), this process was designed to help scaffold students approach to problem solving (albeit mathematical problems) in a way that emphasises the planning process and helps students to inhibit jumping in with little purpose or

direction in mind. Adapting the 6Ss approach to choosing a work experience placement may start with something like Table 1 below. This table is not intended to show a model approach to making the decision nor a mechanism to be adopted for doing so. It is an example of how executive functions can be scaffolded within a planning process that young people may be routinely asked to perform anyway. This level of scaffolding will not be appropriate for all students but provides an example of how existing resources can be used within a strategic shift to focus upon executive functions and decision-making.

QuickSmart 6Ss	**Possible adaption to choosing a work experience placement**
SEARCH: Understand the problem: Underline the question.	Choosing a work experience placement. What do I want to get out of it?
SORT: Understand the problem: Identify what information is important to solve the problem.	How will I decide what work experience to do? What will I need to find out to help me decide?
SEE: Understand the problem: Visualise the problem to help you understand it – in your head, on paper, in a table, putting down ideas.	Consider some of the options. Think through what a typical workday might look like. What characteristics are likely to lead to success? What am I likely to find difficult? How can I prepare for that?
SELECT: Plan: Select the operation(s) you will use to solve the problem.	Create a short list and set some criteria for making the final decision. Think about which criteria must be met and which are desirable.
SOLVE: Solve it: Use your number facts and mathematical knowledge to work out the answer.	List the positive and negative aspects of each possible placement against the criteria. Choose the placement that best meets your criteria.
SENSE: Check: Does your answer make sense?	How do you feel about that decision? Is there anything concerning you? Think about how those concerns might be addressed.

Table 1: Adaption of a problem solving approach to scaffolding the use of executive functions in decision-making

The Australian Curriculum also presents opportunities and requirements for students to plan processes before embarking upon them. For example, in the draft science curriculum, Year 5 and 6 students are expected to "With guidance, plan appropriate investigation methods to answer questions or solve problems" through to Year 7 and Year 8 when they need to "Collaboratively and individually plan and conduct a range of investigation types, including fieldwork and experiments, ensuring safety and ethical guidelines are followed".

Enhancing students' view of themselves as active participants in future education and employment remains important in this age range, particularly as the social aspects on cognition, self-concept and decision-making become highly influential (Blakemore, 2008, Choudhury et al., 2008).

As highlighted in the colour change across Figure 2, **beyond 15 years** of age executive functions are approaching adult levels. Using the language of SOLO (see Part Four above), this shift in young people coincides with them beginning to access the Formal mode. In this mode, individuals seek to understand the relationships between concepts as their thought processes become more abstract and they move beyond the need for concrete referents. Beyond 15 years, young people begin to question ideas, formulate their own hypotheses within specific disciplines and recognise general principles.

In general, young people are now in a position where they have at their disposal a full range of executive functions and a nascent ability to think in abstract terms and escape not only from the moment but from their past experiences and their immediate surroundings. They are becoming sophisticate in their future-orientation like never before and developing an understanding of complex ideas with numerous components and relationships between those components. In combination, these cognitive abilities lay strong foundations upon which decision-making and planning skills can be built.

Interventions are now likely to be based on providing support for young people to actually make the decisions about their first steps along their career pathway, including making their next academic and vocational education choices.

Identifying the levels of executive functioning of individual 15 to 25 year olds can be difficult. As described above, for less demanding tasks they can operate at the level that is indistinguishable from adults but when greater demands are made and a number of executive functions are required to work together the differences between this group and adults become apparent (e.g., Anderson & Anderson, 2001, Cauffman et al., 2010).

The challenge in supporting young people in this age range is in providing appropriate levels of scaffolding. Too little and they might go through the motions of decision-making and end up on a particular pathway with little purpose or engagement. Too much scaffolding and they may be limited to thinking about their planning processes in terms of bite-sized chunks missing some of the important subtleties that they could access if left to their own relational thinking.

The shift in reward sensitivity around eighteen years suggests that until this age career advisers may need to add some evaluation steps to the career planning process to help young people perform a “reality check” on the potential pros and cons of their decisions.

In considering young people’s view of themselves and the level of agency that they perceive they have in the career planning process, the senior secondary years present particular challenges. A focus on the summative assessment processes that will lead to final school grades and university entry scores is likely to push students into an entity view of their intelligence (Blackwell, et al., 2007). As discussed, self-categorisation in this way can limit students, such that there is an impulse to focus on maximising grades rather than undertaking appropriate learning toward identified goals. Cultural influences can reinforce this self-concept, for example, students who are likely to receive high Australian Tertiary Admission Rank (ATAR) can feel pressured to avoid courses that require lower ATAR scores in favour of courses with a higher admissions requirement even if they are inappropriate for their plans and aspirations.

The use of *neuromyths* that drive other forms of self-categorisation (e.g., preferred learning styles and left-brain/right-brain thinkers) is particularly prevalent with this age group when career planning and is to be avoided. A future-orientation (with a "reality check") is more appropriate such that an individual can identify their educational needs in order to meet the goals they have set for themselves. Self-categorisation reinforces inflexibility and takes options away from young people. **[See recommendation #11, page 41]**

Part Eight

Areas of recommendation

1. *Levelling the playing field*

A focus on improving young people's executive functioning will help them to make higher quality decisions and will likely improve their outcomes in education, employment and health. Evidence also suggests that doing so will go some way to "levelling the playing field" between young people from different socioeconomic backgrounds.

2. *Continual challenge*

Improvement in executive functioning can be made at any age (from pre-school to early adulthood) but **continually supporting that development throughout the age range** is most advantageous. This requires an awareness of the level at which individual students are working and **practices that are responsive** to their needs in order to continually stretch and develop their executive function skills.

3. *Professional learning for career advisers and other educators*

Programs around the world that have been successful in building the executive function skills that underpin students' decision-making have included **professional learning for educators**. External commercial providers and expensive resources are not necessary where **capability and capacity can be built** within the existing workforce. Other adults such as parents, mentors, industry representatives, etc., who support young people's decision-making may benefit from learning more about executive functions. This would help them to implement a strategic shift in which day-to-day activities are used to foster executive function skills, and also to target the support they might give to young people during decision-making processes.

4. *Physical exercise*

The **combination of exercise and mindful practices** have consistently been shown to improve executive functioning in young people. Ensuring students undertake frequent, regular physical activity for an extended period (30 minutes or more each session) will likely improve their decision-making skills.

5. *Use of technology*

Other than working memory, the skills that support decision-making do not seem to be transferable from “brain training” and other computer activities. Technology may be useful for providing information, etc., but **not for supporting the development of executive function**. For students who have low levels of executive functioning and find it difficult to make career plans and stick to them, **technology may provide ways to scaffold the decision-making process** and support students to implement the plans.

6. *Broad approaches, practice and more practice*

There is no quick-fix to developing decision-making and planning skills in young people. Approaches that target specific executive functions have limited success in terms of their transferability. Broad authentic approaches in which young people can **practise using their decision-making and planning skills** are most likely to lead to successful outcomes. There are many opportunities for them to do so within existing classroom activities and curricula but **a strategic shift** is required. The need for young people to practise appropriately using their inhibitory control, working memory, cognitive flexibility, and decision-making and planning skills cannot be overemphasised.

7. *Wellbeing*

Student wellbeing is crucially important to both the development of decision-making skills and for young people to be able to use the skills they have effectively. For students experiencing challenges that impact upon their wellbeing more scaffolding and support will be required in their career planning processes.

8. *Scaffolding*

Some students seem to develop their executive functions and decision-making skills for themselves but for others scaffolding of decision-making processes is required. Mechanisms and programs for doing so may be beneficial including the use of **organisers, memory aids or tangible reminders**. Examples are given in the report of processes that can help scaffold students development of executive function and decision-making skills. **It is equally important that tasks are not over-scaffolded** and that students are not constantly repeating low-level tasks when they would be capable of engaging with activities that would place more demand on their executive functions.

9. *Supporting the development of decision-making skills versus supporting decision-making.*

Some young people will find themselves in situations where they need to make decisions and plans about their careers though they may not have the underlying cognitive skills to do so. In these situations it is important to **support the decision-making itself**. This should be considered as quite distinct from **supporting the development** of decision-making and planning skills. The processes for supporting decision-making may include some scaffolding (as described in the report) or **using the executive function skills of others** as a surrogate for the students lower level skills. This may be achieved by career advisers, teachers, parents, mentors or even through technology solutions.

10. Avoiding categorisation

The well-intentioned use of neuromyths such as ideas about preferred learning styles, left-brain/right-brain thinkers, etc. actually drive students to categorise themselves and limit their outcomes. **The use of these ideas to define who students are and who they might become should be replaced by more optimistic future-oriented approaches.** Similar forms of student self-categorisation on the basis of sex, gender, ethnic origin, etc., should be discouraged and **a proactive approach to developing young people's self-concept should be adopted.** This applies in particular to young people's **view of themselves as learners** which, if focussed on performance rather than learning and development, impacts upon their educational outcomes and the decisions they make (including in career planning).

11. Intervention timeline

Figure 2 of the report shows an indicative timeline for the development of executive functions and planning skills. This scheme (and a consideration of the SOLO modes and levels) can help inform the design of career development interventions that should take into **consideration the likely level of cognitive skills of the target age group**. Three broad phases have been highlighted and some specific types of intervention have been exemplified.

> **Five to ten year olds: practising and developing executive function skills** (e.g., working together to build reasoned opinions, taking managed risks).
>
> **Ten to fifteen year olds: practising and developing planning skills** (e.g., working with scenarios, authentic problem solving, using opportunities in the Australian Curriculum). Learning the process should be the focus but the content can also be relevant to career planning.
>
> **Beyond fifteen years old: putting it into action and maintaining a focus on development** (e.g., directing the developed planning skills and capacity for abstract thought to authentic and personal future-oriented decision-making). Responsiveness to young people's need for support within the decision-making process is crucially important for this group. Scaffolding needs to be at an appropriate level for each individual (i.e., sufficient but not so much that the process becomes simplistic and fragmented).

References

Adams, J. (1995) *Risk* London:UCL Press

Albert, D. & Steniberg, L. (2011). Age differences in strategic planning as indexed by the Tower of London. *Child Development*, 82 (5), 1501-1517.

Anderson, V. A. & Anderson, P. (2001). Development of executive functions through late childhood and adolescence in an Australian sample. *Developmental Neuropsychology 20* (1) 385-406

Andrews-Hanna, J. R., Mackiewicz Seghete, K. L., Claus, E.D., Burgess, G. C., Ruzic, L. & Banich, M. T. (2011). Cognitive Control in Adolescence: Neural Underpinnings and Relation to Self-Report Behaviors. *Plos ONE, 6*(6), 1-14.

Arnsten, A. F. T. (1998) The biology of being frazzled *Science 280*, 1711-1712

Ashcraft, M. H. & Kirk, E. P. (2007) The relationships among working memory, math anxiety, and performance. *Journal of Experimental Psychology: General, 130* (2) 224-237.

Ashcraft, M. H. & Krause, J. A. (2007) Working memory, math performance, and math anxiety. *Psychonomic Bulletin & Review, 14* (2) 243-248.

Australian Curriculum (2011) Retrieved 10th November 2011 from Australian Curriculum website http://www.australiancurriculum.edu.au/Science/Curriculum/F-10

Beltz, A., Swanson, J., and Berenbaum, S. (2011). Gendered occupational interests: Prenatal androgen effects on psychological orientation to Things versus People. *Hormones and Behavior, 60* (4), 313-317

Best, J. R., Miller, P. H. & Jones, L. L. (2009). Executive functions after age 5: Changes and correlates. *Developmental Review, 29,* 180-200.

Biggs, J. & Collis, K. (1982) *Evaluating the quality of learning: The SOLO Taxonomy.* New York: Academic Press.

Biggs, J. & Collis, K. (1991). Multimodal learning and the quality of intelligent behaviour. In H. Rowe (Ed.), *Intelligence, Reconceptualisation and Environment* (pp. 57-76). New Jersey: Lawrence Erlbaum Associates.

Biggs, J. B., & Moore, P. J. (1993). *The process of learning* (3rd ed.). Australia: Prentice Hall.

Blackwell, L. S., Trzesniewski, K. H. & Dweck, C. S. (2007) Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. *Child Development, 78* (1) 246-263

Blakemore, S-J., (2008). The social brain in adolescence. *Nature Reviews Neuroscience, 9,* 267-277.

Blakemore, S-J. & Choudhury, S. (2005). *The Learning Brain: Lessons for Education.* Oxford: Wiley-Blackwell

Blakemore, S-J. & Frith, U. (2006). Development of the adolescent brain: implications for executive function and social cognition. *Journal of Child Psychology and Psychiatry, 47* (3/4), 296-312.

Bodrova, E & Leong, D. J., (2006) Self-Regulation as a Key to School Readiness. In Zaslow, M. & Martinez-Back, L (Eds.) *Critical Issues in Early Childhood Professional Development* Baltimore: Brookes

Bodrova, E & Leong, D. J., (2007) *Tools of the Mind: The Vygotskian Approach to Early Childhood Education*. New York: Merrill/Prentice Hall.

Burgh, G. (2006) *Philosophy activities: philosophy in schools*. Retrieved 10th November 2011 from http://www.uq.edu.au/hprc/index.html?page=21377

Cacioppo, J. & Patrick, W., (2008) Loneliness: Human Nature and the Need for Social Connection New York:Norton.

Casey, B. J., Somerville, L. H., Gotlib, I. H., Ayduk, O., Franklin, N. T., Askren, M. K., Jonides, J., Berman, M. G., Wilson, N. L., Teslovich, T., Glover, G., Zayas, V., Mischel, W. & Shoda, Y. (2011) Behavioral and neural correlates of delay of gratification 40 years later. *Proceedings of the National Academy of Science, USA, 108* (36) 14998-15003

Cauffman, E., Shulma, E. P., Steinberg, L., Claus, E., Banich, M. T., Graham, S. & Woolard, J. (2010) Age differences in affective decision-making as indexed by performance on the Iowa Gambling Test. *Developmental Psychology, 46* (1) 193-207.

Centre on the Developing Child at Harvard University (2011). Building the Brain's "Air Traffic Control" System: How Early Experiences Shape the Development of Executive Function: Working Paper 11 http://www.developingchild.harvard.edu

Chan, C.C., Tsui, M. S., Chan, M. Y. C. & Hong, J. H. (2002). Applying the Structure of the Observed Learning Outcomes (SOLO) Taxonomy on student's learning outcomes: An empirical study. *Assessment & Evaluation in Higher Education, 27*(6), 511-527.

Chouldhury, S., Charman, T. & Blakemore, S-J. (2008). Development of the Teenage Brain. *Mind, Brain, and Education, 2* (3), 142-146. Coffield, F., Moseley, D., Hall, E. & Ecclestone, K. (2004), *Learning styles and pedagogy in post-16 learning. A systematic and critical review,* London: Learning and Skills Research Centre, retrieved 10th November 2011 from https://crm.lsnlearning.org.uk/user/order.aspx?code=041543

Coffield, F., Moseley, D., Hall, E. & Ecclestone, K. (2004), *Should we be using learning styles? What research has to say to practise,* London: Learning and Skills Research Centre, retrieved 10th November 2011 https://crm.lsnlearning.org.uk/user/order.aspx?code=041540

Collis, K.F., Jones, B.L., Sprod, T., Watson, J.M. & Fraser, S.P. (1998) Mapping development in students' understandings of vision using a cognitive structural model. *International Journal of Science Education, 20*(1), 45-66.

Dawson, P. & Guare, R. (2010). *Executive Skills in Children and Adolescents, Second Edition: A Practical Guide to Assessment and Intervention.* New York: Guilford

Diamond, A., Barnett, W. S., Thomas, J., Munro, S., (2007) Preschool Program Improves Cognitive Control. *Science 318,* 1387-1388

Diamond, A. & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science, 333,* 959-964

Dingwall, K. M. & Cairney, S. (2010) Psychological and cognitive assessment of Indigenous Australians. *Australian and New Zealand Journal of Psychiatry. 44,* (1) 20–30

Dumontheil, I., Houlton, R., Christoff, K. & Blakemore, S-J. (2010). Development of relational reasoning during adolescence. *Developmental Science, 13* (6), 15-24. Eccles, J.S., 1994. Understanding women's educational and occupational choices: applying the

Eccles et al. model of achievement-related choices. *Psychol. Women Q. 18,* 585–609.

Engle, P. M. J., Santos, F. H., & Gathercole, S. E. (2008). Are working memory measures free of socioeconomic influence? *Journal of Speech, Language, and Hearing Research, 51* (6) 1580–1587.

Geake, J. (2008). Neuromyths in Education, *Educational Research, 50* (2), 123-133

Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H. (2004). The structure of WM from 4 to 15 years of age. *Developmental Psychology*, 40, 177–190.

Gathercole, S. E. & Packiam-Alloway, T. (2008). *Working Memory and Learning: A practical guide for teachers*. London: SAGE Publications

Gogtay, N., Giedd, J. N., Lusk, L., Hayashi, K. M., Greenstein, D., Vaituzis, A. C., Nugent, T. F., Herman, D. H., Clasen, L. S., Toga, A. W., Rapoport, J. L., & Thompson, P. M. (2004) Dynamic mapping of human cortical development during childhood through early adulthood. *Proceedings of the National Academy of Sciences, USA, 101* (21) 8174-8179

Goldberg, E. (2001) *The executive brain: Frontal lobes and the civilized mind.* New York: Oxford University Press

Goswami U. (2006) Neuroscience and education: from research to practice? *Nature Reviews Neuroscience 7,* 406-413

Green, C. S. & Bavelier, D (2003) Action video game modifies visual selective attention. *Nature 423,* (6939) 534-537

Grosbras, M-H., Jansen, M., Leonard, G., McIntosh, A., Osswald, K., Poulsen, C., Steinberg, L., Toro, R. & Paus, T. (2007). Neural Mechanisms of Resistance to Peer Influence in Early Adolescence. *The Journal of Neuroscience, 27* (30), 8040-8045.

Halpern, D.F., Benbow, C.P., Geary, D.C., Gur, R.C., Hyde, J.S., Gernsbacher, M.A., 2007. The science of sex differences in science and mathematics. *Psychol. Sci. Pub. Int. 8*, 1–51.

Han, S. & Northoff, G. (2008) Culture-sensitive neural substrates of human cognition: a transcultural approach. *Nature Reviews Neuroscience. 9* (8) 646-654

Hattie, J., Biggs, J. & Purdie, N. (1996). Effects of learning skills interventions on student learning: A meta-analysis. *Review of Educational Research, 66* (2) 99-136.

Heatherton, T. F. (2011). Neuroscience of Self and Self-Regulation. *Annual Review of Psychology, 62,* 363-390.

Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008) Be smart, exercise your heart: exercise effects on brain and cognition *Nature Reviews Neuroscience 9* (1) 58-65.

Howard-Jones, P. A. (2009). Scepticism is not enough. *Cortex, 45* (4) 550-551

Howard-Jones, P. A., Ott, M., van Leeuwen, T. & De Smedt, B. *Neuroscience and technology enhanced learning.* Retrieved 10th November 2011 from the FutureLab website http://www.futurelab.org.uk/resources/neuroscience-and-technology-enhanced-learning

Hughes, C. (2011). Changes and Challenges in 20 Years of Research Into the Development of Executive Functions. *Infant and Child Development, 20* 251-271.

Huettel, S. A., Stowe, C. J., Gordon, E. M., Warner, B. T. & Platt, M. L. (2006). Neural signatures of economic preferences for risk and ambiguity. *Neuron, 49* 765-775

Huizinga, M., Dolan, C. V. & van der Molen, M. W. (2006). Age-related change in executive function: Developmental trends and a latent variable analysis. *Neuropsychologia, 44,* 2017-2036.

Ireson, J. & Hallam, S. (2009). Academic self-concepts in adolescence:Relations with achievement and ability grouping in schools. *Learning and Instruction, 19* (3) 201-213

Jaeggi, S. M., Buschkuehl, M., Jonides, J. & Perrig, W. J. (2008) Improving fluid intelligence with training on working memory. *Proceedings of the National Academy of Sciences USA 105* (19) 6829-6833.

Kaufman, C. *Executive function in the classroom: Practical strategies for improving performance and enhancing skills for all students*. Baltimore: Paul H. Brookes Publishing Co.

Klimkeit, E. I., Mattingley, J. B., Sheppard, D. M., Farrow, M., & Bradshaw, J. L. (2004). Examining the development of attention and executive functions in children with a novel paradigm. *Child Neuropsychology*, 10, 201–211.

Klingberg, T. (2010) Training and plasticity of working memory. *Trends in Cognitive Science 14* (7) 317-324

Kubesch, S., Walk, L., Spitzer, M., Kammer, T. Lainburg, A., Heim, H. & Hille, K. (2009) A 30-minute physical education program improves students' executive attention. *Mind, Brain and Education. 3* (4) 235-242

Levin, H. S., Culhane, K. A., Hartmann, J., Evankovich, K., Mattson, A. J., Harward, H., Ringholz, G., Ewing-Cobbs, L., & Fletcher, J. M. (1991). Developmental changes in performance on tests of purported frontal lobe functioning. *Developmental Neuropsychology, 7,* 377-395.

Levins, L. & Pegg, J. (1993). Students' understanding of the concepts of plant growth. *Research in Science Education*, 23, 165–175.

Lipman, M (2003) *Thinking in Education,* 2nd edn, Cambridge:Press Syndicate of the University of Cambridge

Lipman, M, Sharp A and Oscanyan, F (1980) *Philosophy in the Classroom.* Philadelphia:Temple University Press.

Lamm, C., Zelazo, P. D. & Lewis, M.D. (2006). Neural correlates of cognitive control in childhood and adolescence: disentangling the contributions of age and executive function. *Neuropsychologia, 44,* 2139-2148.

Lindell, A. K. & Kidd, E. (2011) Why right-brain teaching is half-witted: a critique of the misapplication of neuroscience to education. *Mind, Brain and Education 5,* (3) 121-127.

Luria, A. R. (1966) *Higher Cortical Functions in Man.* New York: Basic Books

Margo, J., Dixon, M., Pearce, N., & Reed, H. (2006). *Freedom's orphans: raising youth in a changing world* London: Institute for Public Policy Research

McCloskey, G., Perkins, L. A. & Van Divner, B. (2008) *Assessment and Intervention for Executive Function Difficulties*. New York: Routledge.

Meltzer, L. (2009) *Promoting Executive Function in the Classroom (What Works for Special-Needs Learners).* New York: Guilford.

Meltzer, L. & Krishnan, K. (2007) Executive function difficulties and learning disabilities. In Melzer, L. (Ed.) *Executive Function in Education: From Theory to Practice* New York: Guilford Press

Mischel, W., Shoda, Y. & Rodriguez M. L. (1989). Delay of gratification in children. *Science, 244,* (4907) 933-938

Moffitt, T. E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, HL., Houts, R., Poulton, R., Roberts, B. W., Ross, S., Sears, M R., Murray Thomson, W. & Caspi, A. (2011). A Gradient of childhood self-control predicts health, wealth, and public safety. *Proceedings of the National Academy of Science, USA, 108* (7), 2693-2698.

Murphy, M. C. & Dweck, C. S., A culture of genius: how an organization's lay theory shapes people's cognition, affect, and behaviour. *Personality and Social Psychology Bulletin, 36* (3) 283-296.

Nussbaum, A. D. & Dweck, C. S. (2008) Defensiveness versus remediation: self-theories and modes of self-esteem maintenance. *Personality and Social Psychology Bulletin, 34* (5) 599-612.

Olesen, P. J., Westerberg, H., & Klingberg, T. (2004) Increased prefrontal and parietal activity after training of working memory. *Nature Neuroscience 7* (1) 75-79

Owen, A. M., Hampshire, A, Grahn, J. A., Stenton, R., Dajani, S., Burns, A. S., Howard, R. J. & Ballard, C. G. (2010) Putting brain training to the test. *Nature 465* (7299) 775-5778

Panizzon, D. (2003). Using a cognitive structural model to provide new insights into students' understandings of diffusion. *International Journal of Science Education, 25* (12), 1427-1450.

Panizzon, D. & Pegg,J. (2008). Assessment practices: Empowering mathematics and science teachers in rural secondary schools to enhance student learning. *International Journal of Science and Mathematics Education, 6,* 417-436.

Pegg, J. (2003). Assessment in mathematics: A developmental approach. In M. Royer (Ed.), *Mathematical cognition* (pp. 227-259). Greenwich, Conneticut: Information Age Publishing.

Pegg, J. & Tall, D. (2005). The fundamental cycle of concept construction underlying various theoretical frameworks. *The International Journal of Mathematics Education, 37*(6), 468-475.

Pegg, J. (2011). Personal Communication

Polya, G. (1945). *How to Solve It: A new aspect of mathematical method*. Princeton: Princeton University Press.

Purdie, N. (1998). The power of the SOLO model to address fundamental measurement issues. In B. Dart & G. Boulton-Lewis (Eds.), *Learning and teaching in higher education* (pp. 145-176). Melbourne: ACER.

Romer, D., Betancourt, L. M., Brodsky, N. L., Giannetta, J. M., Yang, W. & Hurt, H. (2011) Does adolescent risk taking imply weak executive function? A prospective study of relations between working memory performance, impulsivity, and risk taking in early adolescence. *Developmental Science. 14 (*5) 1119-1133

Rosser, J. C, Lynch, P. J. Cuddihy, L., Gentile, D. A., Klonsky, J. & Merrell, R. (2007) The impact of video games on training surgeons in the 21st century. *Archives of Surgery 142* (2) 181-186

Royal Society (2011) *Brain Waves Module 2: Neuroscience: implications for education and lifelong learning*. Retrieved from http://royalsociety.org/uploadedFiles/Royal_Society/Policy_and_Influence/Module_2_Neuroscience_Education_Full_Report.pdf

Sebastian, C., Burnett, S. & Blakemore, S-J. (2008). Development of the self-concept during adolescence. *Trends in Cognitive Sciences, 12* (11), 441-446.

Senn, T. E., Espy, K. A., & Kaufmann, P. M. (2004). Using path analysis to understand executive function organization in preschool children. *Developmental Neuropsychology*, 26, 445–464.

Shallice, T. (1990) Specific impairments of planning. *Philosophical Transactions of the Royal Society of London B, 298*, 199-209

Sharp, J.G., Bowker, R. & Byrne, J. (2008) VAK or VAK-uous? Towards the trivialisation of learning and the death of scholarship. *Research Papers in Education*, 23, (3), 293-314.

Shaw, P., Greenstein, D., Lerch, J., Clasen, L., Lenroot, R., Gogtay, N., Evans, A., Rapoport, J. & Giedd, J. (2006). Intellectual ability and cortical development in children and adolescents. *Nature, 440, 676-679.*

Steinberg, L. (2005) Cognitive and affective development in adolescence. *Trends in Cognitive Sciences 9* (2) 69-74 Stuss, D. T. & Benson, D. F. (1986) *The frontal lobes* New York: Raven

Tierney, J. (2011) Can a playground be too safe? *New York Times*. Retrieved 10th November 2011 from http://www.nytimes.com/2011/07/19/science/19tierney.html

Tulley, G. & Spiegler, J. (2009) *Fifty dangerous things (you should let your children do)* Montara CA: Tinkering Unlimited

Watson, J., Collis, K., Callingham, R., & Moritz, J. (1995). A model for assessing higher order thinking in statistics. *Educational Research and Evaluation, 1*(3), 247-275.

Weisberg D. S., Keil F. C., Goodstein J., Rawson E., & Gray J. R. (2008). The Seductive Allure of Neuroscience Explanations. *Journal of Cognitive Neuroscience. 20* (3), 470–477.

Welsh, M. C., & Pennington, B. F., & Groisser, D. B. (1991). A normative-developmental study of executive function: A window on prefrontal function in children. *Developmental Neuropsychology, 7,* 131-149.

Wong, C. S. P. (2007). Views on the adoption and implementation of the SOLO Taxonomy. In S. Frankland (Ed.), *Enhancing teaching and learning through assessment: Deriving an appropriate model* (pp. 4-15). Dordrecht, The Netherlands: Springer.

Zelazo, P. D. & Müller, U. (2002) Executive function in typical and atypical development. In Goswami, U. (Ed.) *Blackwell handbook of childhood cognitive development*. Oxford: Blackwood

Appendix 1: Elaboration of the SOLO Model

Prior to the emergence of neuroscience research much of education and our understandings of learning and teaching were based in the cognitive domain. While there are many theories that fit under this broad umbrella, the Structure of the Observed Learning Outcome (SOLO) Model is a cognitive model based upon classroom research. Developed by John Biggs and Kevin Collis in the late 1970s, it has been used as a theoretical framework in higher education (Chan et al., 2002; Purdie, 1998; Wong, 2007), science education (Collis et al., 1998; Levins & Pegg, 1994; Panizzon, 2003), mathematics education (Pegg & Tall, 2005; Watson et al., 1995) and assessment (Panizzon & Pegg, 2008; Pegg, 2003). An underlying premise of the model is

> that there are 'natural' stages in the growth of learning any complex material or skill and that in certain important aspects these stages are similar to, but not identical with, the developmental stages in thinking described by Piaget and his co-workers (Biggs & Collis, 1982, p. 15).

In their work they observed a consistent pattern of learning (i.e., learning cycle) displayed by students for a variety of school-related tasks across subjects. While initially drawing upon Piaget's theory of stage development, SOLO attempts to address criticisms of Piaget's theory by focusing on the complexity evident in students' responses. This differed from the work of Piaget who was concerned with identifying developmental stages that had an invariant quality that changed only after considerable time.

The underlying focus of the SOLO Model is around the *quality of learning* demonstrated in a response with understanding being viewed as an individual characteristic that is both *content* and *context specific*. Importantly, it is recognized that the structure of any student response may be influenced by a number of extraneous factors including motivation, intention, and prior learning strategies (Panizzon, 2003).

Importantly, as a model that conceptualizes student cognitive growth providing rich insights into the nature of how students acquire understandings, it has wide applicability to the classroom. Additionally, it provides a framework that is particularly useful in developing teaching programs and/or curricula that reflect student development.

Modes of thinking

There are two key features underpinning the SOLO model: modes of thinking and levels of complexity. The five modes are termed sensori motor, ikonic, concrete symbolic, formal, and post formal. These modes represent different, broad ways of thinking or operating, determined by the nature of the elements being employed for a task or activity.

Sensori motor mode: This mode becomes available at birth and encompasses the coordination of actions and the learning of motor skills within the physical

environment. As this type of knowledge involves *knowing how* to complete a physical task, it is termed tacit knowledge. Importantly, this mode plays an important role throughout life particularly in relation to the development of sporting skills.

Ikonic mode: Accessibility to this mode occurs at about 18 months of age as actions become internalized by the individual resulting in the use and development of language and imagery. Young children in this mode use stories and mythical characters to explain human interactions while adults use the mode to assist in appreciating music, art and literature. Thinking intuitively is an everyday example of adults working within the ikonic mode.

Concrete symbolic mode: In the majority of cases this mode becomes available at around five to six years of age. It involves a major shift in abstraction as concepts and operations are applied through the symbolic systems of written language, number, and musical notation. These systems require internal logic and order or *knowing what* as individuals describe their world using symbolic descriptions. It is this mode that is addressed most commonly with learning in the primary and secondary school.

Formal mode: Individuals begin to access this mode at approximately 16 years of age. Within this mode, individuals seek to understand the relationships between concepts as their thought processes become more abstract and they move beyond the need for concrete referents. Hence, they are able to question ideas, formulate their own hypotheses within specific disciplines, and recognize general principles. This is considered as the highest level of abstraction required in professional practice and at an undergraduate level.

Post formal mode: Usually attained from around 20 years of age but is the most difficult to describe. It is demonstrated in postgraduate study where the conventional principles of a discipline are questioned and explored further so that the knowledge of the discipline expands. This is where individuals push the theoretical boundaries of the time. However, there is some debate about the existence of this mode.

Essentially, these modes become available in sequential order with each newly acquired mode co-existing with the earlier acquired mode. In this way prior modes continue to develop throughout life, often assisting (or perhaps impeding) developments in a later acquired mode (Watson et al., 1993). The modes and the approximate age of availability are illustrated in Figure 1. The diagram also includes four arrows (A, B, C, and D) and these refer to important pathways of development within the SOLO model highlighting different aspects of intellectual functioning (Biggs & Collis, 1991).

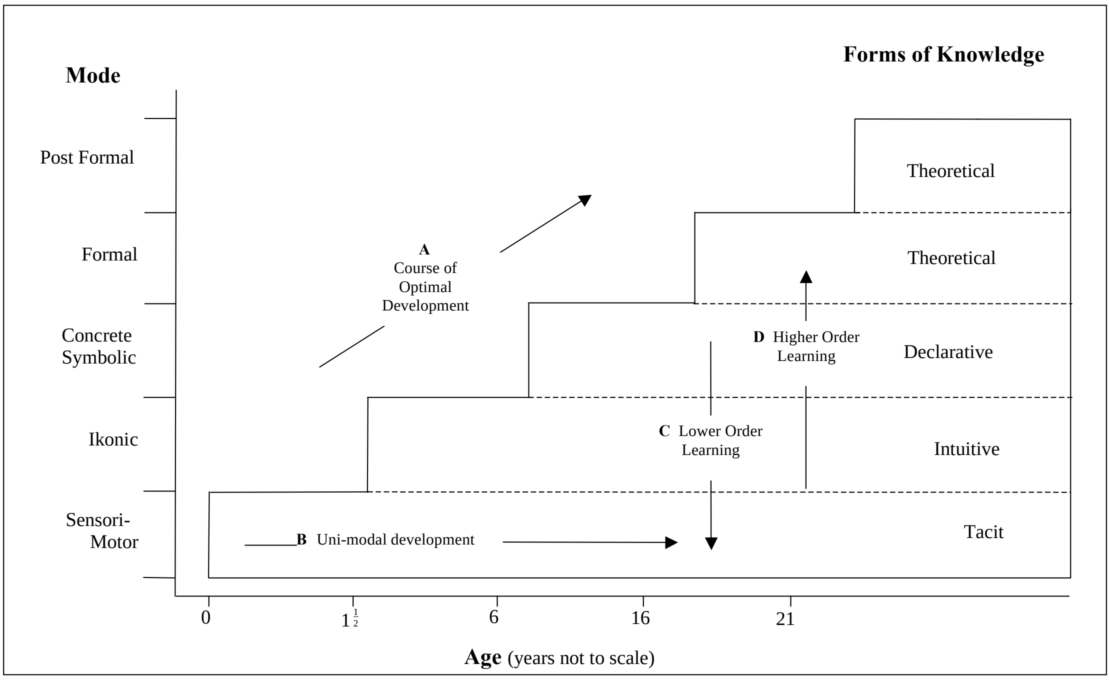

Figure 1. Modes of thinking (Adapted from Biggs & Collis, 1991)

While these modes represent the level of abstraction at which individuals of a particular age may commonly function, in most instances we utilize these modes in a number of ways depending upon the learning context.

- Arrow A represents the *course of optimal development* assumed by theorists, such as Piaget, where an emerging stage replaces the earlier stage. The SOLO model considers that learning in earlier acquired modes supports the development of higher modes. This mirrors reality where individuals are able to access all acquired modes throughout their lifetime.
- Arrow B represents a path of unimodal functioning and represents the most straight-forward case of learning. In the case of very young children (i.e., less than 18 months) unimodal functioning is expected as only one mode is available and this is the sensori motor. The target mode for primary and secondary education is the concrete symbolic mode. However, an important issue for teachers is that when addressing learning from a purely concrete symbolic approach (i.e., ignoring characteristics of the ikonic and sensori motor modes) the subject matter can become decontextualized and hence not offer the student an appropriate developmental pathway based on the natural growth of their understanding. An example of this in mathematics is when students are not given access to manipulatives with teachers requiring students to *work it out in their heads*.

  A result of this approach is that what is learned in school is seen by students as being irrelevant to their real world. As a balance to this issue, teachers need to be conscious of which mode is the target mode for instruction. If a teacher spends too long outside of the target mode then the student may also be disadvantaged (as is the case when teachers spend too much time on 'doing' experiments in secondary science (drawing on sensori motor and ikonic

modes) and not addressing, in the concrete symbolic mode (the target mode), the scientific results and implications of what is being investigated.

In contrast, arrows C and D represent multimodal learning, which could be considered most relevant to classroom teachers. In these cases there is a target mode but teachers evoke and address other acquired modes to support of student learning in their lessons.

- Arrow C is termed top-down learning as it identifies those instances when an individual uses higher-order modes to improve their performance in an earlier acquired mode. This is demonstrated when athletes working predominantly in the sensori motor mode, watch videos (ikonic mode), or read books (concrete symbolic mode), and analyze an opponents game (Formal mode) to improve their performance. However, the point must be made again that too much emphasis outside of the target mode will not help the athlete and that most training needs to be based, or directed at, skills and understandings associated with the sensori motor. Hence, the coach's focus on practice and drill with the athlete so that movement and action becomes automated.
- Arrow D is referred to as bottom-up learning as earlier acquired modes are used to support learning in a higher target mode. For example, this approach is common in science classes when students undertake investigations (involving lots of sensori motor activity), view and talk about demonstrations (illustrating the ikonic mode), come to use and explain phenomenon using science language and ideas (concrete symbolic mode) to facilitate their understanding of an abstract concept or principle within the formal mode. It is this type of learning that is supported by constructivist theory in science (Biggs & Moore, 1993).

Consequently, with the exception of young children working in the sensori motor mode, there are a number of modes available to an individual in any learning situation.

Levels of functioning

In addition to modes, Biggs and Collis (1991) identified differences in performances within a specific mode that shared common characteristics – termed levels. These levels demonstrate a hierarchy in the learning of a task from novice to expert within each mode of functioning. The three major levels identified for any mode are: unistructural (U), multistructural (M), and relational (R). As a collective, they are referred to as *a learning cycle* (i.e., U-M-R). Description of these levels include:

- Unistructural: Indicates that the individual has understood the task but can only identify *one piece* of relevant information.
- Multistructural: Occurs when the individual is able to identify *two or more pieces* of data relevant to the question but these data are seen in isolation so that there is a lack of integration.

- Relational: Demonstrates that the learner is able to identify a number of elements that are consistent with the question or activity and *relate them to one another* around a particular concept or idea.

These three levels are relevant to development in each mode. In some of the earlier writings of SOLO two further levels entitled *prestructural* (P) and *extended abstract* (EA) were used to allow descriptors for responses that fell outside of the concrete symbolic mode (the only mode in which detail work had been undertaken at the time). However, in the latest evolution of the SOLO model (from 1991) these levels are not used.

Critically, the SOLO Model acknowledges that there are transition levels. Here, the response from students usually shares features in common with two adjacent levels. For example, a transition level between unistructural and multistructural responses would include one relevant aspect (the unistructural code) and an unsuccessful (perhaps vague) attempt to incorporate a second relevant aspect. In the case of transition from multistructural to relational the response would include several relevant aspects and a vague or incomplete attempt to relate the aspects or identify a general rule.

The advantage of the SOLO model is that it links these cycles of learning (i.e., growth through U-M-R) with the hierarchical nature of cognitive development (i.e., growth through the sensori motor, ikonic, concrete symbolic, formal and post formal modes). The interaction between modes of thinking and levels of complexity are illustrated in Figure 2.

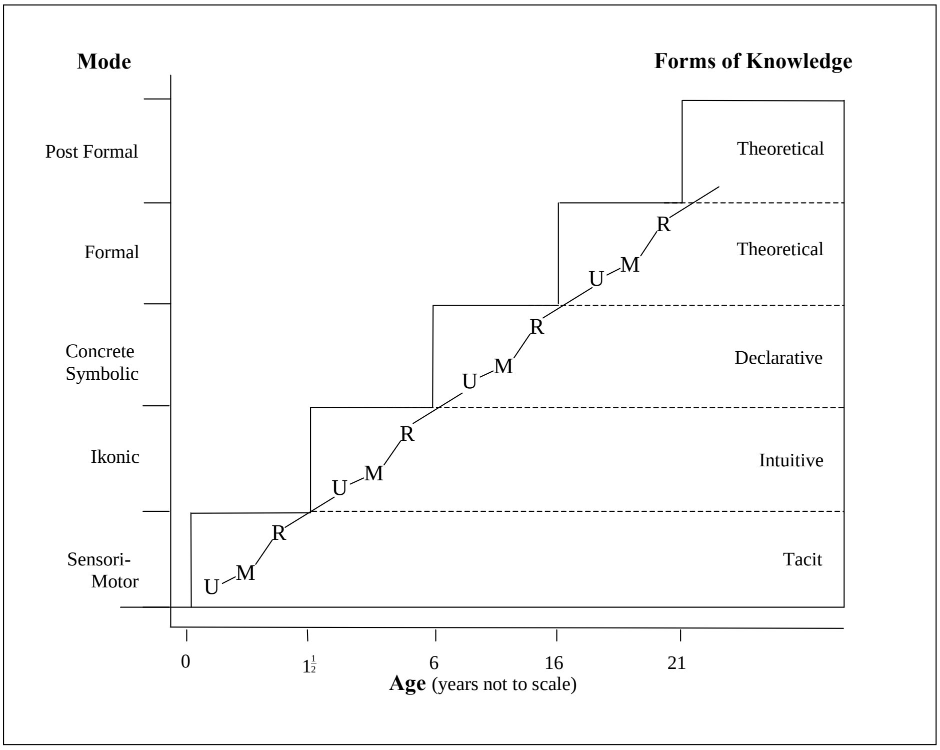

Figure 2. Learning cycles within modes of the SOLO model

(Adapted from Biggs & Collis, 1991)

In summary

- Modes appear additively
- The U-M-R cycle of learning cycle occurs within all modes
- Increasing competence within any given mode leads to a particular kind of knowledge
- Particular tasks require the integration of several modes (Biggs & Collis, 1991).

Two learning cycles within a mode

Emerging from research studies across a number of school years was the realization that a single U-M-R cycle within a mode did not accommodate the range of responses offered by students. In particular, it was difficult to interpret responses from many primary students, low-achieving secondary students, or adults new to a particular area of study within the single learning cycle model.

As a consequence of a closer, more detailed examination of these responses an earlier cycle of levels (i.e., a new U-M-R cycle) was identified. Importantly, the responses coded at these levels still shared the characteristics of the same mode and so led to at least two learning cycles within each mode relevant to primary and secondary education in the concrete symbolic and formal modes (Levins & Pegg, 1994; Panizzon, 2003). These cycles are distinguished by U_1-M_1-R_1 and U_2-M_2-R_2 as represented in Figure 3.

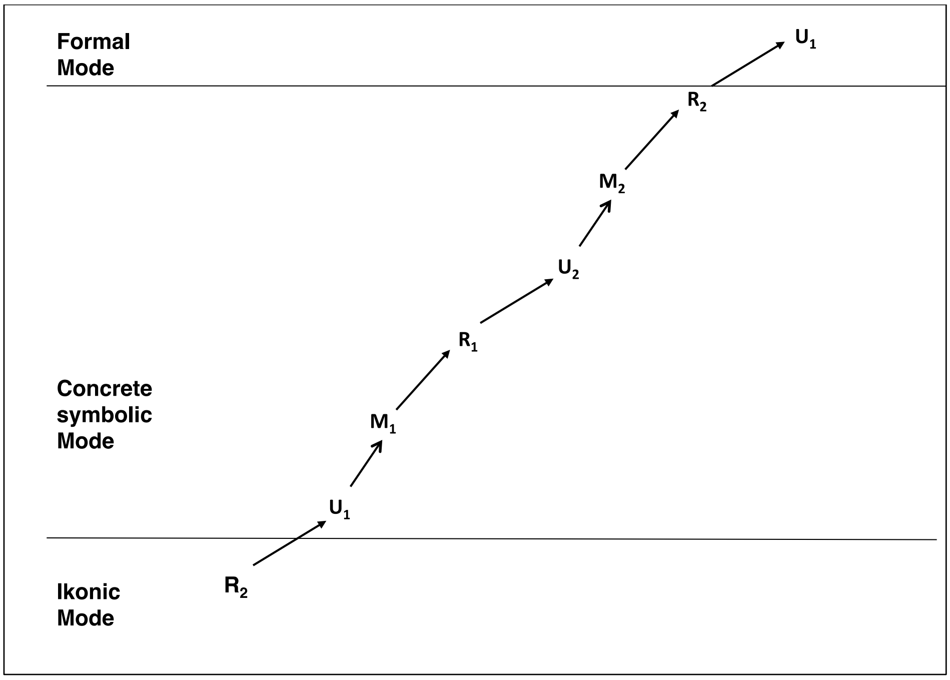

Figure 3. Two learning cycles in the concrete symbolic mode

In considering the two cycles, a U_1 response identifies one aspect or feature, the M_1 response provides two or more aspects and the R_1 demonstrating integration of aspects into a cohesive statement or 'story'. From research findings, the U_1-M_1-R_1 cycle appears to be more concerned with developing a 'global picture' or macroscopic idea of the concept being developed without depth evident. It is often very descriptive with a strong image base being influenced by the ikonic mode. For example, a review of 200 responses from Year 8 students regarding their explanations of day and night revealed that a large proportion of these students conceptualized the Earth as the central object with the sun and moon orbiting it. So even though they had been taught about the heliocentric model governing the movement of objects in our solar system in their science lessons, they had constructed quite a different view.

However, with time, the relationship identified at R_1 requires less working memory so that students are able to focus more closely on the more detailed aspects of the question or activity. This leads to the second cycle in the concrete symbolic mode i.e., U_2-M_2-R_2. This cycle involves explanations around the *cause and effect* or a focus around explaining *why* a process occurs. Referring again to the day and night example, responses categorized in the U_2-M_2-R_2 cycle focused around the detail underpinning the cause of day and night on the Earth. Students recognized that it was the rotation of the Earth on its axis that was critical to the amounts of light received on Earth. Of course, this is a major idea for explaining why different parts of the Earth experience different hours of day and night, which change in relation to seasons. Of critical importance though is that it is here (in this second cycle) where teachers in upper primary and secondary schools would traditionally direct their teaching while being the target for textbooks.

Hence, a critical point to stress is that in focusing teaching on the U_2-M_2-R_2 cycle, there will be a proportion of students in any class who are still operating in the U_1-M_1-R_1 cycle for the concept being taught. Hence, it is not surprising that these students may be disengaged with their learning while teachers find it difficult to meet their learning needs. Essentially, these students require quite different pedagogical approaches and depth of content than their peers already operating in the U_2-M_2-R_2 cycle.

It is important to note that one learning cycle is not better than another, it is just that one group of students are conceptually further developed for a particular concept than others at this point in time. However, given the appropriate time and experiences, the students in the U_1-M_1-R_1 cycle should progress into the next learning cycle. Similarly, just because students are operating in the U_2-M_2-R_2 cycle for one concept does not mean that their understanding will be as well developed for another concept. This is a critical distinction between the stage theory of Piaget and the multi-modal perspective offered by the SOLO model.

Student progress through modes and levels

The modes and learning cycles within the SOLO model provide a sequence for cognitive growth. This raises the question as to why is it that some of our students demonstrate much deeper understandings than others even though they experience the same teaching situation? Biggs and Collis (1991, p.67) identified five factors that influence the transition from one mode to the other and one level to the next.

1. Physical maturation refers to physiological changes in the individual with age due to increased brain size and functioning, and the improvement in neuronal transmission as a consequence of development in the myelin sheath. Clearly, this links with much of the work in the neuroscience area.

2. Progress into a subsequent mode requires that the individual has attained the relational level in the previous mode. This is because within the SOLO model, each level is a prerequisite for the succeeding step into the following mode.

3. The availability of working memory within the individual relates to physical maturity and the increased ability of working memory to undertake more advanced processing with age. Seemingly, older children have a greater capacity for processing information than younger children, which affects the type of response produced. As an answer to a question is structured, the individual must keep the question in mind and then relate their answer to the question.

4. Social support and interaction with others often enhances the developmental growth of an individual. For example, parents initiate cognitive change by providing scaffolding, modeling, and content for their children (Biggs & Moore, 1993). This view supports the notion of social constructivism and the work by Vygotsky (1978) around the *zone of proximal development* and the important role of others in the learning process.

5. Confrontation with a problem is the final factor likely to initiate change from one mode to another. Modal shifts usually occur when individuals are forced to reorganize their prior knowledge in an attempt to solve a new problem. We see this frequently in the classroom when students struggle to grasp information teachers have presented during a lesson and when asked to explain the issue, many struggle to verbalize it aloud. This is referred to as *cognitive conflict*.

Consequently, shifts in thinking result from a combination of these five factors, which have important implications for teachers and the school curricula. While aspects of physical maturation and the capacity of the working memory are intrinsic to the individual, teachers must consider social support and the provision of challenging problems carefully so that modal transition is encouraged in their classrooms.

Developing thinking from novice to expert

Another body of research around novices and experts further supports the acquisition, organization and structure of understandings discussed so above. This research explains that having constructed our understandings over time based upon our experiences and prior knowledge – teachers, specialists (i.e., scientists, economists, mathematical modelers), and other adults (e.g., master chess players) demonstrate an expertise in their respective fields that is quite different when compared to others who might be considered *novices*. Subsequently, experts approach their work using a perspective or conceptual framework (schemata) that is structurally and functionally very different to novices (Bransford et al., 2004).

Much of the earlier work in this area was derived from DeGroot (1965) who investigated the thinking used by master chess players and compared it to that of novices. The findings from this work indicated that masters in the game were able to conceptualize possible moves or patterns in a game, realizing the potential of particular strategies. Bransford et al (2004) suggest that in structuring and organizing their understandings around key patterns, there is less demand on the working memory as the patterns become automatically recognized.

Importantly, many of the findings from this initial chess-based research are identifiable for experts in all fields (Bransford et al., 2004). For example, expertise in a domain ensures that individuals develop sensitivities to patterns of meaningful information that are not evident with novices. To exemplify this point further, electronics technicians are able to reproduce circuit diagrams after viewing them for a few seconds because they tend to think about potential groupings based upon structure and function, not on the individual components. Similarly, mathematicians quickly recognize specific problem types that involve classes of mathematical solutions rather than tackling each individual problem.

A fundamental difference between the two groups is that experts tend to structure their knowledge and/or understandings around core concepts/ideas or 'big ideas', which then guide their thinking within domains of knowledge. In science this is often around generalizable principles or laws (e.g., Newton's laws of motion) whereas historians develop systemic ways of making sense of contradictory historical documents even within areas where they are not 'historical experts'. It is this ability to use broader structures in their thinking and analyses rather than focusing upon individual facts that empowers the experts (Bransford et al., 2004).

Coming from quite diverse perspectives means that experts need to think carefully about how they communicate with novices in these fields – they need to be able to *bridge the gap.* This is not always an easy task because in becoming an expert one loses a sense of what it is like to be learning new information or developing new understandings. Ensuring communication requires some consideration of the following questions:

- What knowledge should be presented?
- What concepts/ideas comprise this knowledge?
- When is the optimum time to present these concepts/ideas?
- In what order should they be introduced and then developed?
- How should they be presented?
- What kinds of experiences do the learners need in preparation?
- When should these experiences be provided?

References

Biggs, J. & Collis, K. (1982) *Evaluating the quality of learning: The SOLO Taxonomy*. New York: Academic Press.

Biggs, J. & Collis, K. (1991). Multimodal learning and the quality of intelligent behaviour. In H. Rowe (Ed.), *Intelligence, Reconceptualisation and Environment* (pp. 57-76). New Jersey: Lawrence Erlbaum Associates.

Biggs, J. B., & Moore, P. J. (1993). *The process of learning* (3rd ed.). Australia: Prentice Hall.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2004). *How people learn: Brain, mind, experience and school*. Washington, DC: National Academy Press.

Chan, C.C., Tsui, M. S., Chan, M. Y. C. & Hong, J. H. (2002). Applying the Structure of the Observed Learning Outcomes (SOLO) Taxonomy on student's learning outcomes: An empirical study. *Assessment & Evaluation in Higher Education*, *27*(6), 511-527.

Collis, K.F., Jones, B.L., Sprod, T., Watson, J.M. & Fraser, S.P. (1998) Mapping development in students' understandings of vision using a cognitive structural model. *International Journal of Science Education, 20*(1), 45-66.

DeGroot, A.D. (1965). *Thought and choice in chess*. The Hague, Netherlands: Mouton.

Drummond, R.J. & Ryan, C.W. (1995). *Career counseling: A developmental approach*. Englewood Cliffs, NJ: Merrill/Prentice Hall.

Hansen, L.S. (1976). *Toward an expanded concept of career education: An examination of the definitions and concepts of career education*. Washington, DC: National Advisory Council for Career Education.

Levins, L. & Pegg, J. (1993). Students' understanding of the concepts of plant growth. *Research in Science Education*, 23, 165–175.

Magnuson, C.S. & Starr, M.F. (2000). How early is too early to begin life career planning? The importance of the elementary school years. *Journal of Career Development*, *27*(2), 89-101.

Panizzon, D. (2003). Using a cognitive structural model to provide new insights into students' understandings of diffusion. *International Journal of Science Education, 25*(12), 1427-1450.

Panizzon, D. & Pegg, J. (2008). Assessment practices: Empowering mathematics and science teachers in rural secondary schools to enhance student learning. *International Journal of Science and Mathematics Education, 6, 417-436.*

Pegg, J. (2003). Assessment in mathematics: A developmental approach. In M. Royer (Ed.), *Mathematical cognition* (pp. 227-259). Greenwich, Conneticut: Information Age Publishing.

Pegg, J. & Tall, D. (2005). The fundamental cycle of concept construction underlying various theoretical frameworks. *The International Journal of Mathematics Education*, *37*(6), 468-475.

Purdie, N. (1998). The power of the SOLO model to address fundamental measurement issues. In B. Dart & G. Boulton-Lewis (Eds.), *Learning and teaching in higher education* (pp. 145-176). Melbourne: ACER.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Watson, J., Collis, K., Callingham, R., & Moritz, J. (1995). A model for assessing higher order thinking in statistics. *Educational Research and Evaluation, 1*(3), 247-275.

Wong, C. S. P. (2007). Views on the adoption and implementation of the SOLO Taxonomy. In S. Frankland (Ed.), *Enhancing teaching and learning through assessment: Deriving an appropriate model* (pp. 4-15). Dordrecht, The Netherlands: Springer.